IDA

Status of DoD's Capability to Estimate the Costs of Weapon Systems: 1999 Update

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PREFACE

The Institute for Defense Analyses (IDA) prepared this document for the Office of the Director, Program Analysis and Evaluation, under a task entitled "Cost Research Symposium." It contains an assessment of DoD's capabilities to estimate the costs of weapon systems. The assessment was originally presented by a panel of representatives from the Office of the Secretary of Defense and the Military Departments at the 32nd Annual DoD Cost Analysis Symposium conducted on February 3–5, 1999, in Williamsburg, Virginia.

Because it contains no original analysis, the document did not undergo internal IDA review. The document is presented in the form of an annotated briefing.

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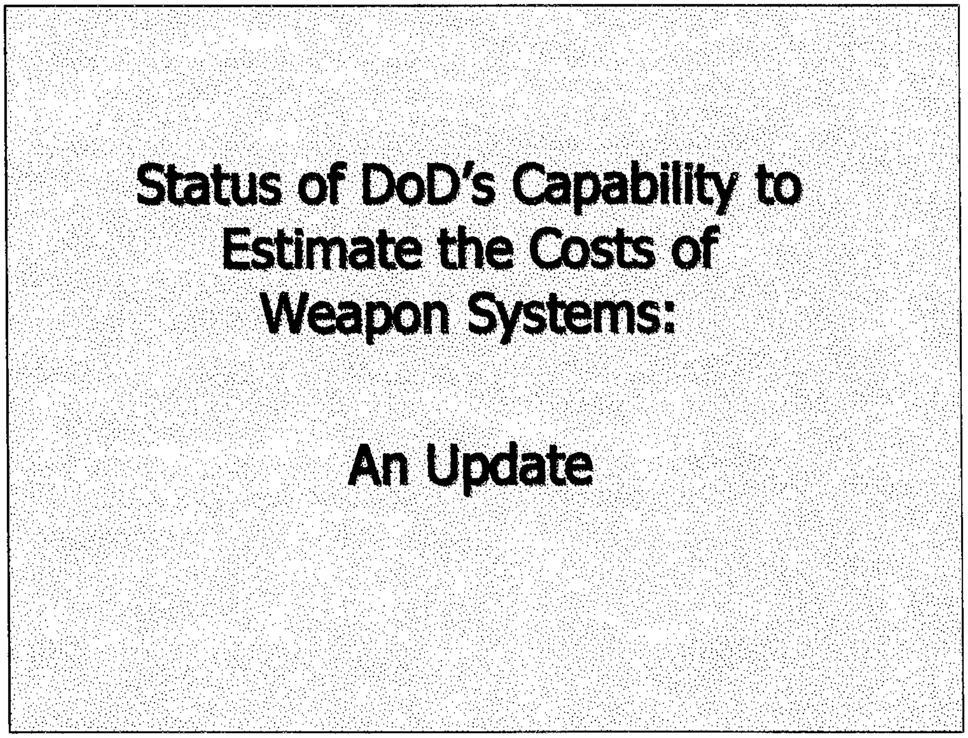
I. INTRODUCTION

Stephen J. Balut, Institute for Defense Analyses

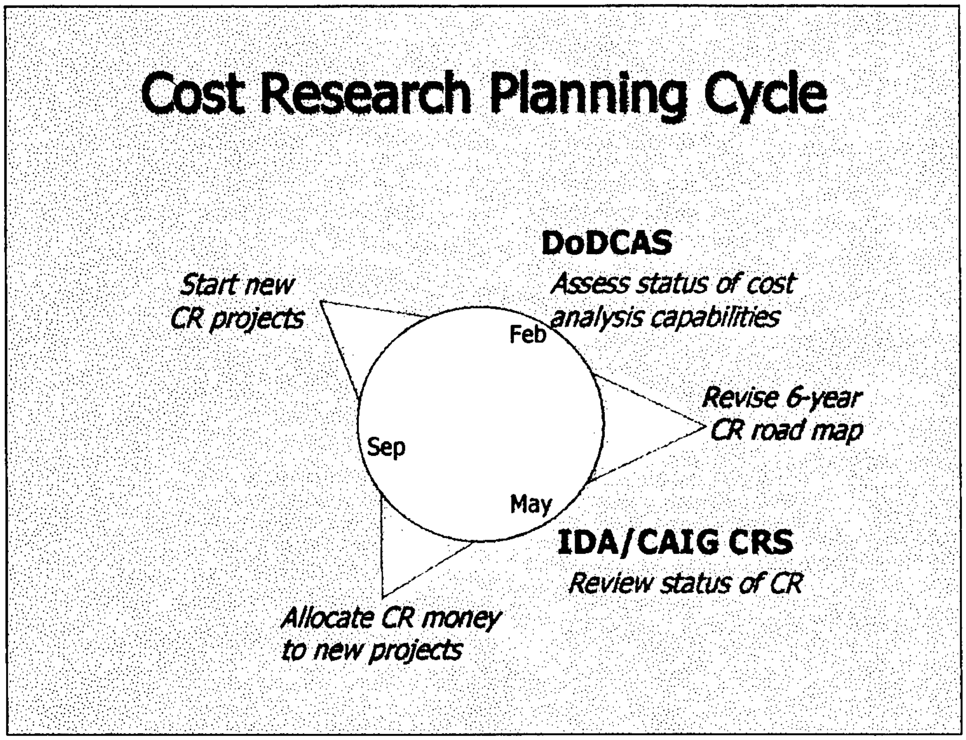


Good morning. As Louis Rukyser says, welcome back. Last year, our panel gave you an assessment of the DoD's capability to estimate the costs of weapon systems. Some of you gave us suggestions on how that assessment could be improved. We thank you for that. We're here with an updated assessment that reports one year of progress and also incorporates your suggestions.

As you know, the purpose of cost research is to develop and improve the data and methods we use to conduct cost analyses.

The current level of our capabilities to do cost analyses and estimate the costs of weapon systems is no accident. It has been determined, in large part, by the data in our safes and the methods on our shelves *right now*. These data and methods are the results of prior investments in cost research. Likewise, our future capabilities will be determined by the investments we make today and tomorrow.

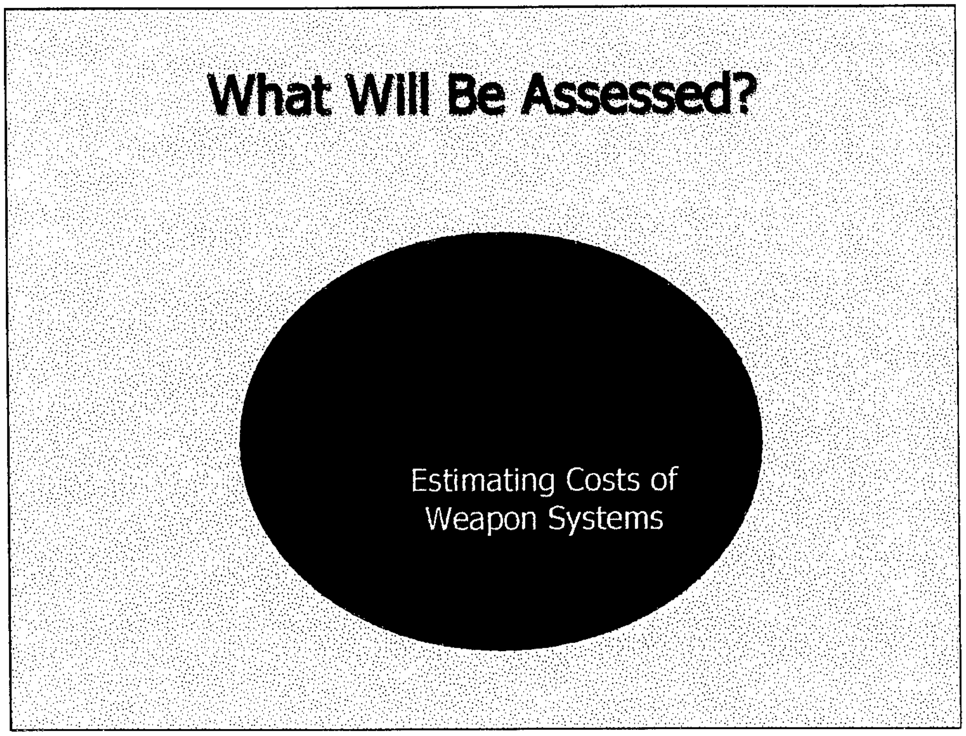
Because cost research dollars are scarce, we must plan for their use carefully. Our investment decisions must be informed in several ways. First, we need an understanding of our current capabilities and a view of where improvement is needed the most in light of pending challenges. Just as important, decisions about where improvement is needed (which we make in a decentralized way) should be made with the knowledge of where *other* research sponsors are making their investments.



This slide shows the cost research (CR) planning cycle that has evolved in the DoD. The process imposes some order and even efficiency on the process by which sponsors choose to invest their scarce cost research dollars. The two main events in this cycle are the DoD Cost Analysis Symposium (DoDCAS) and the IDA/Cost Analysis Improvement Group (CAIG) Cost Research Symposium (CRS).

Obviously, you know about DoDCAS because you're here. At this meeting, we learn the status of DoD's cost analysis capabilities—through meetings, training sessions, and panel discussions.

Some of you may not be familiar with the IDA/CAIG CRS. It was initiated to answer the following question: What cost research is going on today, and, to the extent known, what's planned for tomorrow? The symposium started 10 years ago. I was sitting at my desk thinking about what I was going to spend my independent research dollars on. I realized I knew nothing at all about what other offices were doing now or what they were planning to do. I picked up my phone and invited my colleagues to come to IDA and exchange information. Our meeting resulted in more informed decisions on what investments to make. In addition, we exchanged data and findings and even decided to jointly fund certain research projects of common interest. We've been meeting each year for the same purpose ever since. The CAIG started co-sponsoring the symposium in 1993.

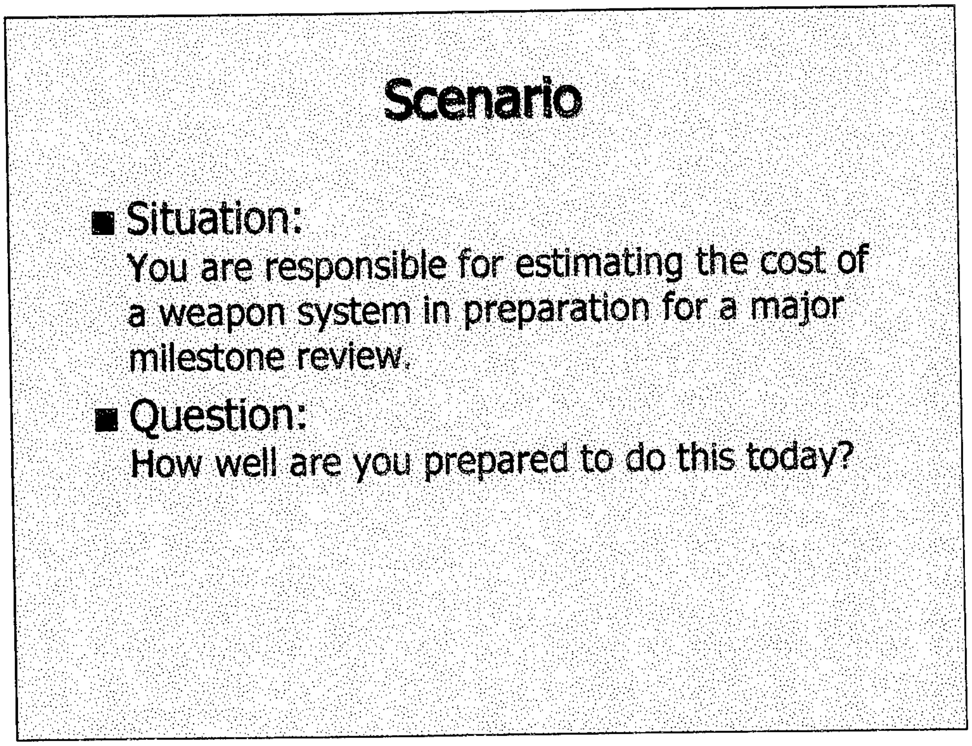


Our panel members are going to present assessments of capabilities as of right now. These assessments reflect the data we—the entire defense cost community—have in our safes and the methods we have on our bookshelves right now.

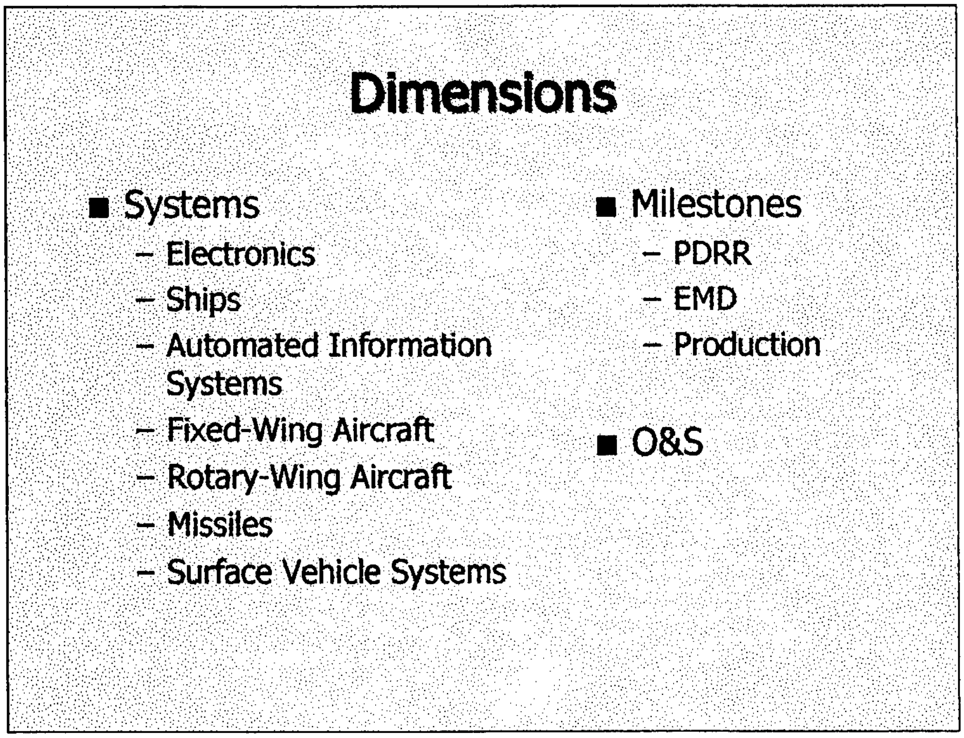
The assessments will not address all areas of cost analysis. We simply don't have enough time to do that in an hour. Our assessment will be limited to the DoD's capability to estimate the costs of weapon systems and, because they are of high interest, automated information systems. Assessments were derived by first talking to the people in the DoD who actually do these estimates and then aggregating their individual subjective judgments.

Now, let's be clear on what is *not* addressed in today's assessments. They do not explicitly include the effects of the so-called "revolution in business affairs"—the effects of acquisition reform, acquisition streamlining, Integrated Product Teams (IPTs) and the like. These effects are being studied now and have yet to be incorporated into our cost-estimating toolbox. Also, our focus on weapon systems excludes force and infrastructure cost estimating. We hope to provide assessments of those areas next year.

So—referring now to the slide—the planning cycle starts with an assessment of cost analysis capabilities here at DoDCAS. This results in identification of areas where *more* research is needed. You'll see these areas in a few minutes. The 6-year Cost Research Plan is updated during the spring, based on what we know at the time of DoDCAS. Then, all *ongoing* cost research activities are reviewed and cataloged at the IDA/CAIG Cost Research Symposium. At about this time, sponsors with cost research money are ready to make their investment decisions for the next fiscal year. At this point, they know the status of existing capabilities, including areas where more research is needed, and they have visibility into ongoing research. The allocations of funds to new research projects are made in the summer.



This slide shows the question that was put to cost analysts in DoD offices that are responsible for estimating the costs of weapon systems. It asks for a subjective assessment of capability to estimate the costs of a specific weapon system at the time of a specific milestone decision. For example, how good is your capability to estimate the cost of a tactical aircraft at the time of an Engineering and Manufacturing Development (EMD) (Milestone II) decision? How good is your capability later, at the time of the Production milestone decision? One would expect capability to be better at the Production milestone because more data, including costs experienced during EMD and Low-Rate Initial Production (LRIP), would be available.



Assessments will be provided for all major commodities included in Military Standard 881B, except ordnance. Once again this year, we were unable to obtain enough information to develop a meaningful assessment of ordnance.

Assessments will be provided for the three major hardware milestones and also for Operations and Support (O&S). The question put to the experts about O&S costs was not related to any specific milestone; instead, it asked for just a general assessment.

Scoring

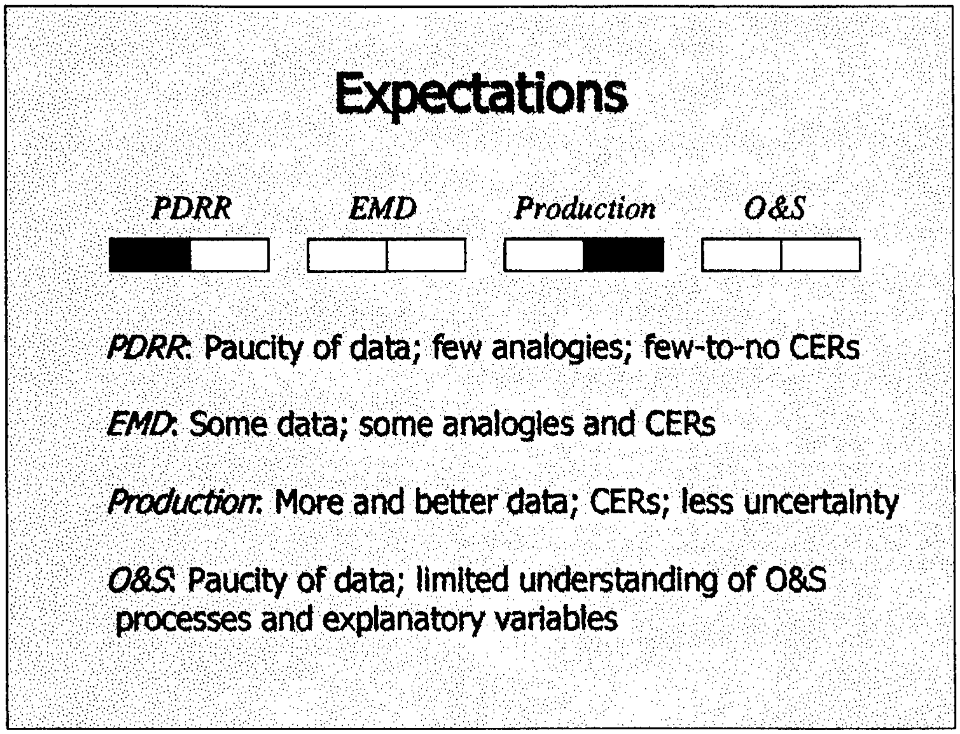
- ***Green***—capabilities good or better
  - Adequate data available
  - CERs/models available and up-to-date
  - Expect small to moderate error in estimates
- ***Yellow***—capabilities marginal
  - Some data available—additional data needed
  - CERs/models available but not current
  - Expect moderate to large errors in estimates
- ***Red***—capabilities poor
  - Data lacking
  - CERs/models not available or of little use
  - Expect large to unknown errors in estimates

Here is the color-coded scoring method used by the experts. Green means capabilities are believed to be good or better. This means adequate data are available now, cost-estimating relationships (CERs)/models are available now, and we feel that the error in estimates will likely be small to moderate.

Yellow indicates a feeling that capabilities are marginal. This means we don't have all the data we need; CERs are around but may not be current or directly applicable, and we might have moderate to large errors in our estimates.

Red means our capabilities are poor. Data are lacking, CERs/models are of little use, and we suspect our estimates may contain errors that are large or worse.

We allowed (and our responders submitted) assessments that included in-between points. So, you will see assessments such as red-yellow and yellow-green. These mean capabilities are judged to be not as bad as the left (or first) color, but not as good as the right (or second) color.



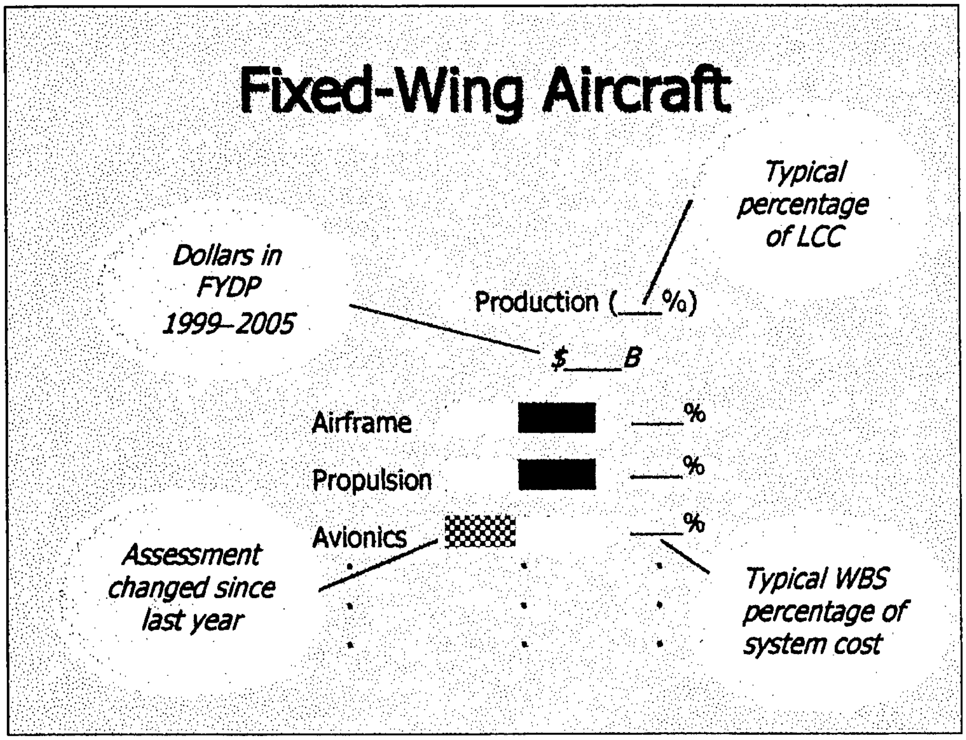
This slide identifies, by phase of development, what we expected the DoD experts to say.

At Milestone I, the decision to enter the Program Definition and Risk Reduction (PDRR) phase, we expected a red-yellow score. At this point, the program being estimated tends to be technically ill-defined. Also, historical databases of weapon systems suffer from a severe lack of PDRR data. And the data that *are* available are of questionable quality. A common problem is inability to distinguish between nonrecurring and recurring hardware costs, that is, design versus build. Another factor contributing to the data void is that contractor costs reported to the government do not include what is quite often moderate to large contractor investments in the PDRR effort. Desire to get the competitive edge in preparation for downselect is a strong incentive to expand internal funding. Finally, in PDRR, there are few if any useful analogies or factors.

At Milestone II, the decision to enter the EMD phase, we expected a yellow score. At this point, the program being estimated tends to be better defined (as compared to Milestone I). Also, historical databases include quite a bit of EMD cost data and associated technical and programmatic data. These data can and have been used to develop estimating methods, including analogies, factors, and parametric relationships.

At Milestone III, the decision to enter the Production phase, we expected a yellow-green score. At this point, the program being estimated tends to be well-defined. EMD is nearing completion and the technical baseline is maturing. Further, historical databases include lots of production cost data and associated technical and programmatic data. Also, analysts doing a Milestone III estimate will have access to actual EMD costs. A variety of cost-estimating methods are available for this milestone, and these methods produce estimates with smaller error and less uncertainty than those for earlier milestones.

We expected DoD experts to report a yellow score for O&S. While Visibility and Management of Operation and Support Cost (VAMOSC) databases include piles of data for active and retired systems, these databases generally do not provide the visibility required to develop a specific estimate at the subsystem or component level. Despite the wealth of historical data, there is a paucity of O&S cost-estimating methodologies, particularly relationships between a given O&S cost element and a system's performance characteristics, such as speed, range, and so on. Without this type of method, it is difficult to conduct cost-performance trade-offs called for by the Cost As an Independent Variable (CAIV) procedure.



This slide highlights how this year's assessments differ from last year's. Most of the differences resulted from your suggestions. The panelists will give you more information to place their assessments in context and give you an idea of their relative importance. I'm using the production column for fixed-wing aircraft as an example here.

First, you'll see a percentage alongside the column heading, in this example, "Production." This is the typical percentage of life-cycle cost (LCC) represented by production costs for fixed-wing aircraft. The percentage was derived using data on a few current fixed-wing aircraft. The sample used was not comprehensive, and the figure shown is a rough estimate.

You'll also see a number below the column heading. This number gives the billions of dollars included in the 1999–2005 Future Years Defense Plan (FYDP) for production of fixed-wing aircraft. Please don't try to multiply the LCC percentage by the FYDP billions. The numbers are not compatible. The FYDP number gives only the FYDP slice, not the whole program.

The percentage next to the work breakdown structure (WBS) elements is the typical percentage of total fixed-wing production costs represented by the particular element. The sum of all WBS element percentages should add to 100.

Finally, the color-coded boxes that represent the assessments will be cross-hatched if the assessment for that item changed since last year. In this example, last year's yellow changed to red, that is, things got worse.

Panel

- *Mr. Richard Collins, NCCA*
  - Electronics
  - Ships
  - Automated Information Systems
- *Ms. Deborah Cann, AFCAA*
  - Space Systems
  - Fixed-Wing Aircraft
- *Mr. Richard Bishop, USACEAC*
  - Rotary-Wing Aircraft
  - Missiles
  - Surface Vehicle Systems
- *Dr. Vance Gordon, OSD CAIG*
  - Summary/OSD Perspective
  - Upcoming DAB Schedule

Now I'd like to introduce our panel and get on with the assessments.

Our first panelist is Mr. Richard Collins. Rick is the Technical Director of the Naval Center for Cost Analysis (NCCA). He coordinates Navy cost research. Before his role as Technical Director, he was head of the Ships and Ship Systems Division of NCCA. Rick worked as a cost analyst at Science Applications International Corporation (SAIC) before joining NCCA. Rick has a master's degree in economics from Virginia Tech and a bachelor's degree in economics from Wake Forest. He will provide assessments for electronics, ships, and automated information systems.

Our second panel member is Ms. Deborah Cann. Debbie is the Research Division Chief at the Air Force Cost Analysis Agency (AFCAA). She is responsible for all the Agency's cost research activities and cost support contracts. Debbie has worked at AFCAA for 7 years, since its inception. Before that, she worked in the Air Staff at SAF/FMC in the Pentagon. Debbie is currently working on an M.B.A. at Strayer University. She will provide assessments for space systems and fixed-wing aircraft.

Our next panel member is Mr. Richard Bishop. Dick is the Chief of Cost Research at the U.S. Army Cost and Economic Analysis Center (USACEAC). He analyzes Army-wide cost research requirements and develops and manages the Army's long-range cost research program. Dick began his government career as an Army Signal Corps Officer. He later worked for IBM as a computer designer. Dick holds a B.S. degree in electronics engineering and an M.S. in

industrial engineering, both from Oklahoma State University. Dick will present assessments for rotary-wing aircraft, missiles, and surface vehicle systems.

Our last panelist is Dr. Vance Gordon. Vance is a member of the Operations Analysis and Procurement Planning Division of PA&E's Resource Analysis Directorate. Since joining this office, Vance has been responsible for development of DoD cost research guidance. He served previously in PA&E's Projection Forces Division. Dr. Gordon is a graduate of the University of Colorado and received his Ph.D. in population biology from Washington University in St. Louis. He will provide a consolidated perspective on DoD's capabilities and identify some future challenges.

II. SPACE SYSTEMS

Deborah Cann, Air Force Cost Analysis Agency

Space Systems

	RDT&E (18%)		Production (66%)
	PDRR	EMD	
Then-Year $ through FYDP:	*$8B*		*$10B*
Integration, Assembly and Test	5%		6%
Software	13%		0%
Spacecraft	8%		13%
Payload	37%		42%
Ground C3	9%		13%
Test and Evaluation	1%		0%
SE/PM/Data/Training	15%		5%
Support Equipment	4%		0%
Spares (in O&S)	0%		0%
Launch Operations and Orbital Support	1%		3%
Launch Vehicle	7%		18%

The dollars shown under the phase represent the FYDP years FY 1999 to 2005, and the percentages next to the phase indicate the typical percentage of total life-cycle cost. Individual WBS percentages reflect their portion of the phase in total. Percentages for RDT&E are shown in whole because PDRR and EMD could not be broken out.

The only change noted from last year is in the area of Launch Vehicle.

Launch Vehicle is revised from yellow to green in RDT&E based on Evolved Expendable Launch Vehicle (EELV) contracts recently being awarded through FY 2006. For the next several years, EELV will be the only launch vehicle and prices are set by contract. However, since the contract is only through FY 2006, Production is revised from yellow to yellow/green and not totally green, based on the uncertainty of cost fluctuation in Production after FY 2006.

I'd like to talk about acquisition reform and its effect on our estimating ability because it came up several times in our discussions of ratings for space systems. Last year, we thought that historical data may not take into account contractor initiatives under acquisition reform. However, recent estimates indicate that we are unable to quantify cost savings due to acquisition reform initiatives. Therefore, we are inclined to believe historical databases currently being used are not unreasonable, even for new programs.

Space Systems (cont.)

	O&S (16%)
Mission Personnel	14%
Unit-Level Consumption	12%
Intermediate Maintenance	0%
Depot Maintenance	3%
Contractor Support	2%
Sustaining Support	66%
Indirect Support	3%

On the other hand, it bears mentioning that, due to the expansion of the commercial space industry, DoD space systems are shifting away from state-of-the-art technology toward commercially available technology. For this reason, our historical data may eventually become less useful for estimating future acquisitions.

The bottom line is that historical data at this point is still a viable means of estimating in the space arena.

Software remains the most troublesome area in estimating space systems, although not unlike the other commodities.

There have been no changes in Space O&S. However, the addition of space system data into Air Force Total Ownership Cost (AFTOC) later this year will significantly increase our ability to estimate space systems' O&S costs in the future.

Contributing Organizations

- Air Force Cost Analysis Agency (AFCAA)
- Air Force Space and Missile Systems Center (AF/SMC)

Contributing organizations included AFCAA and AF/SMC.

FYDP Representation

RDT&E

- Global Broadcast Service (GBS)
- National Polar-Orbiting Operational Environmental Satellite System (NPOESS)
- Navy Extremely High Frequency SATCOM (NESP)
- Navigational Strategic, Tactical and Relay (NAVSTAR) Global Positioning System (GPS)
- Evolved Expendable Launch Vehicle (EELV)
- Defense Meteorological Satellite Program (DMSP)
- Space-Based Infrared Systems (SBIRS)
- Titan IV
- Military Strategic, Tactical and Relay (MILSTAR)

Procurement

- GBS
- NESP
- NAVSTAR GPS
- DMSP
- SBIRS
- Titan IV

Note: Not included in the FYDP calculation are Defense Satellite Communications Systems (DSCS) III and Advanced Extremely High Frequency (EHF) programs, due to no Selected Acquisition Report (SAR) reporting as yet.

The systems captured in the FYDP representation are listed here.

Research Efforts Recently Completed and Ongoing

Recently completed:

- Communications Payload and Spaceborne Electronics Cost Model, MCR, 1998
- Small Satellite Cost Model, Aerospace, 1998

Ongoing:

- Satellite Cross-Links Database
- NASA/Air Force Cost Model, CEAC

Area Most in Need of Further Research

- Software

Space Estimating Source List

Integration A&T

- *Small Satellite Cost Model, Aerospace, 1998*
- Unmanned Space Vehicle Cost Model (USCM), Tecolote, 1997, (N/R)
- NASA/AF Cost Model (NAFCOM), SAIC, 1997, (N/R)
- SEER H, Systems Evaluation and Estimation Resources-Hardware, Galorath Associates, 1997
- *Spacecraft Functional CERs, IDA for BMDO, 1996 (N/R)*
- Space Payload Integration Model, Tecolote, 1994
- GPALs CERs, TASC-Arlington, January 1993, (N/R multi-programs)
- NAVSTAR GPS Data, SMC/FMC, unknown, (N/R, 1 program)

Software

- *SEER SEM, Systems Evaluation and Estimation Resources-Software, Galorath, 1998*
- *Sage, Software Engineering, Inc. (SEI), 1995*
- PRICE S, Martin Marietta, 1997
- SMC Software Sizing Database, SMC, 1997
- Software Architecture Sizing & Estimating Tool (SASET), Martin-Marietta, April 1993
- CERs for Space-Based Systems, Defense Communications Agency-DC, April 1991, (N/R, comm. sys)
- Revised Intermediate COCOMO (REVIC), AFCAA, February 1991
- Kantor's Factors, Cost Factors and Est. Relationships, Electronic Sys., April 1990 (S/W productivity)

This is an updated "Space Estimating Source List," which includes all known sources of studies, methodologies, CERs, and so on, for space systems. The sources in italics represent the sources added since last year.

Space Estimating Source List (cont.)

Spacecraft

Small Satellite Cost Model, Aerospace, 1998
Unmanned Space Vehicle Cost Model (USCM), Tecolote, 1997 (N/R)
NASA/AF Cost Model (NAFCOM), SAIC, 1997 (N/R)
PRICE H, General Electric, 1997
SEER H, Systems Evaluation & Estimation Resources-HW, Galorath Associates, 1997
Spacecraft Functional CERs, IDA for BMDO, 1996 (N/R)
Phase I Acquisition Reform, TASC, 1996
Small Satellite Subsystem Cost Model, Aerospace, 1996 (N/R)
TRANSCOST, TransCost Systems, 1995 (N/R)
GPALs CERs, TASC-Arlington, January 1993 (N/R multi-programs)
Digital Signal and Data Processor Model, DSDPM, Tecolote, 1993 (N/R)
Revised Small Satellites, Tecolote, November 1991 (N /T1)
CERs for Space-Based Systems, Defense Communications Agency-DC, April 1991 (N/R, comm.. sys)
EPS ECR, Electrical Power Subsystem, Booz Allen, June 1991 (N / T1)
Electrical Power Systems for SDIO Elements, Booz Allen, June 1991 (Streamlining)
High Reliability Parts, MCR, September 1990 (N/R/O&S)
CERs for Prop & Reaction Control, Applied Research, February 1990 (R)
Large Space Power Systems, Aerospace Corporation, August 1988 (N/R, EPS)
JPL Project Cost Model, Jet Propulsion Lab (N/R)
NAVSTAR GPS Data, SMC/FMC, unknown (N/R, 1 program)

Space Estimating Source List (cont.)

Payload

Communications Payload and Spaceborn Electronics Cost Model, MCR, 1997
Unmanned Space Vehicle Cost Model (USCM), Tecolote, 1997 (N/R)
Price H/M, Martin Marietta, 1997
SEER H, Galorath, 1997
Spacecraft Functional CERs, IDA for BMDO, 1996, (N/R)
Strategic and Exp IR Sensors, Technomics, March 1993 (R)
Passive Space Sensor Model, MCR, May 1992 (N/R)
CERs for Space-Based Sys, Defense Communications Agency-DC, April 1991 (N/R, comm sys)
Scientific Inst Cost Model-SICM, Planning Research, 1991 (N/R)
Digital Signal & Data Processor, DSDPM, Tecolote, September 1991 (N/R)
Nonrecurring parts (costs) for Space Sensors, Aerospace for SMC, October 1991 (N)
Tactical IR Sensor Model, Technomics, February 1991 (R small payloads)
CER Rationale for Brilliant Eyes, Technomics, April 1991 (N/R)
Focal Plane Array Cost Estimating Model, Tecolote, July 1990 (N/R)
CER for R&D Missile Comm, Applied Research, March 1990
Kantor's Factors, Cost Factors and Est. Relationships, Electronic Sys., April 1990 (S/W productivity)
Development Engineering & Below the Line Development Models, Technomics, August 1990 (N)
High Reliability Parts, MCR, September 1990 (N/R/O&S)
Multi-variate Instrument Cost Model, MICM, 1990 (N)
Advanced Space Processor Model, Tecolote, September 1989 (N/R)

Ground C3

Ground Operations Cost Model-GOCM, SAIC, 1996 (N/R)
TRANSCOST, TransCost Systems, 1995 (N/R)
GPALs CERs, TASC-Arlington, January 1993 (N/R multi-programs)
Fiber Optics Network Study, General Research Corporation, October 1989
Construction Cost Estimating Handbook, Applied Research, June 1988 (N/R)
JPL Project Cost Model, Jet Propulsion Lab (N/R)
Space Operations Cost Model-SOCM, SAIC (N/R)

Space Estimating Source List (cont.)

Test and Evaluation

Unmanned Space Vehicle Cost Model (USCM), Tecolote, 1997 (N/R)
NASA/AF Cost Model (NAFCOM), SAIC, 1997 (N/R)
Spacecraft Functional CERs, IDA for BMDO, 1996 (N/R)
GPALs CERs, TASC-Arlington, January 1993 (N/R multi-programs)
CER rationale for Brilliant Eyes, Technomics, April 1991 (N/R, summary of other methods)
Dev. Eng. & BTL Dev. Models, Technomics, August 1990 (N)
Kantors Factors, Cost Factors and Est. Relationships, Electronic Sys., April 1990 (S/W productivity)
Space & Strat Def Updated CERs, MCR, December 1987 (N/R, similar to Passive Space Sensor Model)
NAVSTAR GPS Data, SMC/FMC, unknown (N/R, 1 program)

SE/PM

Small Satellite Cost Model, Aerospace, 1998
Unmanned Space Vehicle Cost Model (USCM), Tecolote 1997 (N/R)
NASA/AF Cost Model (NAFCOM), SAIC, 1997 (N/R)
Spacecraft Functional CERs, IDA for BMDO, 1996 (N/R)
GPALs CERs, TASC-Arlington, January 1993 (N/R multi-programs)
Tactical IR Sensor Model, Technomics, February 1991 (R small payloads)
CER Rationale for Brilliant Eyes, Technomics, April 1991 (N/R, summary of other methods)
Focal Plane Array Cost Est. Model, Tecolote, July 1990 (N/R)
Kantor's Factors, Cost Factors and Est. Relationships, Electronic Sys., April 1990 (S/W productivity)
NAVSTAR GPS Data, SMC/FMC, unknown (N/R, 1 program)

Space Estimating Source List (cont.)

Data

Unmanned Space Vehicle Cost Model (USCM), Tecolote 1997 (N/R)
NASA/AF Cost Model (NAFCOM), SAIC, 1997 (N/R)
GPALs CERs, TASC-Arlington, January 1993 (N/R multi-programs)
CER Rationale for Brilliant Eyes, Technomics, April 1991 (N/R, summary of other methods)
Focal Plane Array Cost Est Model, Tecolote, July 1990 (N/R)
Kantor's Factors, Cost Factors and Est Relationships, Electronic Sys, April 1990 (S/W productivity)
Dev Eng and BTL Dev Models, Technomics, August 1990 (N/R)
NAVSTAR GPS Data, SMC/FMC, unknown (N/R, 1 program)

Training

Unmanned Space Vehicle Cost Model (USCM), Tecolote 1997 (N/R)
NASA/AF Cost Model (NAFCOM), SAIC, 1997 (N/R)
NAVSTAR GPS Data, SMC/FMC, unknown (N/R, 1 program)
Focal Plane Array Cost Est Model, Tecolote, July 1990 (N/R)
Kantor's Factors, Cost Factors and Est. Relationships, Electronic Sys., April 1990 (S/W productivity)
GPALs CERs, TASC-Arlington, January 1993 (N/R multi-programs)
CER rationale for Brilliant Eyes, Technomics, April 1991 (N/R, summary of other methods)
Dev Eng & BTL Dev Models, Technomics, August 1990 (N)

Space Estimating Source List (cont.)

Support Equipment

Unmanned Space Vehicle Cost Model (USCM), Tecolote 1997 (N/R)
NASA/AF Cost Model (NAFCOM), SAIC, 1997 (N/R)
Price H, Martin Marietta, 1997
Seer H, Systems Evaluation & Estimation Resources-H/W, Galorath, 1997
Spacecraft Functional CERs, IDA for BMDO, 1996 (N/R)
GPALs CERs, TASC-Arlington, January 1993 (N/R multi-programs)
CER Rationale for Brilliant Eyes, Technomics, April 1991 (N/R, summary of other methods)
Focal Plane Array Cost Est. Model, Tecolote, July 1990 (N/R)
Kantor's Factors, Cost Factors and Est. Relationships, Electronic Sys., April 1990, (S/W productivity)
Dev. Eng. & BTL Dev. Models, Technomics, August 1990 (N)
Space and Strat Def. Updated CER, MCR, December 1987 (N/R, similar to Passive Space Sensor Model)
NAVSTAR GPS Data, SMC/FMC, not known (N/R, 1 program)

Spares

GPALs CERs, TASC-Arlington, Jan 1993 (N/R multi-programs)
Kantor's Factors, Cost Factors and Est. Relationships, Electronic Sys., April 1990, (S/W productivity)

Launch Operations & Orbital Support

Small Satellite Cost Model, Aerospace, 1998
Unmanned Space Vehicle Cost Model (USCM), Tecolote, 1997 (N/R)
Spacecraft Functional CERs, IDA for BMDO, 1996 (N/R)
TRANSCOST, TransCost Systems, 1995 (N/R)
Construction Cost Est. Handbook, Applied Research, June 1988 (N/R)
Space and Strat Def Updated CER, MCR, December 1987 (N/R, similar to Passive Space Sensor Model)

Space Estimating Source List (cont.)

Launch Vehicle

NASA/AF Cost Model (NAFCOM), SAIC, 1997 (N/R)
Launch Vehicle Cost Model, Tecolote, 1996, (N /T1)
Liquid Rocket Engine Cost Model, Rockwell, 1996 (N/R)
TRANSCOST, TransCost Systems, 1995 (N/R)
Digital Signal and Data Processor Model, DSDPM, Tecolote, 1993 (N/R)

III. FIXED-WING AIRCRAFT

Deborah Cann, Air Force Cost Analysis Agency

Fixed-Wing Aircraft

	RDT&E (20%) PDRR		EMD	Production (39%)
Then-Year $ through FYDP:		*$26B*		*$70B*
Airframe		30%		24%
Propulsion		5%		9%
Avionics		32%		23%
Integration, Assembly and Test		5%		10%
Software (in Avionics and IA&T)		0%		0%
Armament		1%		4%
Test and Evaluation		10%		0%
SE/PM		12%		12%
Data		1%		3%
Training		2%		2%
Support Equipment		3%		8%
Spares		0%		6%

The dollars shown under the phase represent the FYDP years FY 1999 to 2005, and the percentages next to the phase indicate the typical percentage of total life-cycle cost. Individual WBS percentages reflect their portion of the phase in total. Percentages for RDT&E are shown in whole because PDRR and EMD could not be broken out.

The most significant change you'll notice this year is the change from yellow/green to yellow in the PDRR phase in Propulsion, Systems Engineering/Project Management (SE/PM), Data, Training and Support Equipment. This is based on a lack of program definition in this phase as well as a lack of data.

The Air Force and Navy's work on JSF air vehicle CERs has improved analysts' ability to estimate airframe and propulsion. For that reason, Airframe in EMD changed to yellow/green from yellow; although we haven't changed the color rating for Propulsion. Also, our ability to estimate composite materials will be improved with the expected RAND Survey of Composite Factors.

There has not been much improvement in the avionics area; however, AFCAA has Tecolote on contract this FY to update our avionics database to be used to formulate a "bridge" from federated to integrated systems. One glitch we may encounter is that this effort is dependent on our being able to collect data on other integrated systems such as the F-22 and Comanche. However, this coupled with RAND's efforts on a complementary study means there is hope in the future for avionics cost estimating.

Fixed-Wing Aircraft (cont.)

O&S (41%)

Mission Personnel	22%
Unit-Level Consumption	15%
Intermediate Maintenance	8%
Depot Maintenance	13%
Contractor Support	8%
Sustaining Support	26%
Indirect Support	8%

Significant improvements have been made to the Military Aircraft Data and Retrieval System (MACDAR) database. Last year's effort included consistent bucketing and normalization. This year's phase will focus on extending the database to include the F-18E/F.

Software estimating still remains a challenge. Tools to estimate software are available; however, input is subjective to analyst judgment.

Armament remains unchanged, and we still rely on analogies to like systems.

There has also been no change in SE/PM, Data, Training, Support Equipment, and Spares except for the reassessment in PDRR.

Aircraft modification challenges are reflected in the coloring scheme, although it is not broken out separately. Structural and avionics modifications present areas requiring further research. To alleviate some of the challenge, Aeronautical Systems Center (ASC) has contracted with Technomics to develop an Aircraft Integration Model, which is expected to be complete this summer.

I would also like to mention the recently delivered Defense Contractor Overhead Rate Analysis that produced CERs for predicting overhead trends based on business base.

NAVAIR's ability to do more detailed O&S estimates has been increased by having available detailed analyses of several major aircraft platforms. Also, given additional years of VAMOSC data, NAVAIR expects to be able to develop valid CERs that can be applied to new platforms.

Contributing Organizations

- Air Force Cost Analysis Agency (AFCAA)
- Naval Air Systems Command (NAVAIR)
- Naval Center for Cost Analysis (NCCA)
- Air Force Material Command/Aeronautical Systems Center (AFMC/ASC)

Contributing organizations included AFCAA, NAVAIR, NCCA, and ASC.

FYDP Representation

RDT&E	Procurement
ATIRCM/CMWS	Black Hawk (UH-60L)
Joint Strike Fighter (JSF)	ATIRCM/CMWS
E-2C Reproduction	Longbow Apache
F/A-18 E/F	T-45TS
CEC	E-2C Reproduction
C-17A	AV-8B Remanufacture
Airborne Laser (ABL)	F/A-18 E/F
B-1B CMUP/DSUP/JDAM/COMP UP	CEC
F-22	C-17A
JSTARS	C-130J
JPATS	B-1B CMUP/DSUP/JDAM/COMP UP
	F-22
	JSTARS
	AWACS RSIP (E-3)
	JPATS

Research Efforts Recently Completed

- Defense Contractor Overhead Rate Analysis, NAVAIR, 1998 (follow-on)
- MACDAR Fighter Aircraft Database, Tecolote, 1998 (follow-on)
- Advanced Fighter Aircraft Cost Model (JSF), AFCAA, 1998
- Air Force Total Ownership Cost (AFTOC) MIS, MCR, 1998 (follow-on)
- Maintenance Trade Decision Support System, Bionetics Corp., 1998
- NAVAIR O&S Cost Model, Brennan & Associates, Inc., 1998
- Life Cycle Cost Model Development, Brennan & Associates, Inc., 1998

Areas Most in Need of Further Research

- Avionics
- Modifications (structural and avionics)
- Software
- Test and Evaluation

Fixed-Wing Aircraft Estimating Source List

General

Defense Contractor Overhead Rate Analysis, NAVAIR, 1998

Integration Assembly & Test

MACDAR Fighter Aircraft Database, Tecolote, 1998
C3 Platform Integration Cost Model, MCR, 1997
PRICE H, General Electric, 1997
Standard Cost Factors Handbook, NCCA, 1992
Kanter's Factors, Cost Factors and Estimating Relationships, Electronic Sys. Division, April 1990
Aircraft Avionics & Missile System Installation Cost Study, MCR, 1988
Cost Factors for A/C and Missiles, Aeronautical Systems Division, May 1987
A Parametric A/C Avionics and Missile System Installation Cost Model, MCR, 1986

Airframe

MACDAR Fighter Aircraft Database, Tecolote, 1998
Advanced Fighter Aircraft Cost Model, AFCAA, 1998
Composites/Exotic Materials Database, Tecolote, 1997 (N/R)
Advanced Airframe Structural Materials, RAND Study, 1991
Military Tactical Aircraft Development Costs, IDA, 1988
Aircraft Airframe CERs, RAND, 1987 (Total Level)

Propulsion

MACDAR Fighter Aircraft Database, Tecolote, 1998
Advanced Fighter Aircraft Cost Model, AFCAA, 1998
NAVAIR/AFCAA Engine Study, Ketron, 1997 (N/R)
GFE, NAVAIR Database, 1997
Development and Prod. Cost for Military Aircraft Turbine Engines, IDA, 1992
Military Tactical Aircraft Development Costs, IDA, 1988

Here is an updated "Aircraft Estimating Source List," which includes all known sources of studies, methodologies, CERs, and so on, for fixed-wing aircraft.

Fixed-Wing Aircraft Estimating Source List (cont.)

Avionics

MACDAR Fighter Aircraft Database, Tecolote, 1998
GFE, NAVAIR Database, 1997
Price H, HL, M, General Electric, 1997
SEER H, Systems Evaluation & Estimation Resources-HW, Galorath Associates, 1997
A Data Base of Airborne Avionics, Tecolote, January 1995
Kanter's Factors, Cost Factors and Estimating Relationships, Electronic Sys. Division, April 1990
Electronic Systems RDT&E Cost Model, MCR, May 1988
Radar Production Cost Model, MCR, May 1988
Military Tactical Aircraft Development Costs, IDA, 1988
Aircraft Avionics & Missile System Installation Cost Study, MCR, 1988
Black Box Estimator—Electronics Cost Models, Tecolote, November 1987
Cost Impacts of Electronic Boxes due to Basing Modes, Tecolote, September 1987
Electronic Box/Electro-optical Equip Cost Analysis Brief, Tecolote, September 1986
Airborne & Ground Mobile Electronic Box Analysis, Tecolote, September 1986
Electronic Subsystem Integration Estimator, TASC, July 1985

Software

SEER SEM, Systems Evaluation and Estimation Resources-S/W Est Model, Galorath, 1998
Software Development Estimating Handbook—Phase One, NCCA, 1998
Price S, Parametric Review of Info for Costing and Evaluation Software Sizing Model, GE, 1997
SASET, Software Architecture Sizing and Estimating Tool, Martin Marietta, April 1993
Revic, Software Cost Estimating Model, AFCAA, February 1991
Kanter's Factors, Cost Factors and Estimating Relationships, Electronic Sys. Division, April 1990

Armament

MACDAR Fighter Aircraft Database, Tecolote, 1998

Fixed-Wing Aircraft Estimating Source List (cont.)

Test & Evaluation

MACDAR Fighter Aircraft Database, Tecolote, 1998
Advanced Fighter Aircraft Cost Model, AFCAA, 1998
Development Eng. and BTL Development Cost Models, Technomics, Aug 1990
Kanter's Factors, Cost Factors and Estimating Relationships, Electronic Sys. Division, April 1990
Assessing Acquisition Schedules for Tactical Aircraft, IDA 1989
Aircraft Airframe CERs, RAND, 1987 (Total Level)

SE/PM

MACDAR Fighter Aircraft Database, Tecolote, 1998
Advanced Fighter Aircraft Cost Model, AFCAA, 1998
Below the Line Cost Factors, AFCAA, 1998
SE/PM Database, TASC, 1997
Standard Cost Factors Handbook, NCCA, 1992
CER Development for R&D Data and SE/PM, Applied Research, March 1990
Development Eng. and BTL Development Cost Models, Technomics, August 1990
Kanter's Factors, Cost Factors and Estimating Relationships, Electronic Sys. Division, April 1990
Cost Factors for A/C and Missiles, Aeronautical Systems Division, May 1987
Aircraft Airframe CERs, RAND, 1987 (Total Level)

Data

MACDAR Fighter Aircraft Database, Tecolote, 1998
Advanced Fighter Aircraft Cost Model, AFCAA, 1998
Below the Line Cost Factors, AFCAA, 1998
Standard Cost Factors Handbook, NCCA, 1992
HAPCA data, NAVAIR, 1991
Development Eng. And BTL Development Cost Models, Technomics, August 1990
CER Development for R&D Data and SE/PM, Applied Research, March 1990
Kanter's Factors Cost Factors and Estimating Relationships, Electronic Sys Division, April 1990
Cost Factors for A/C and Missiles, Aeronautical Systems Division, May 1987
Aircraft Airframe CERs, RAND, 1987 (Total Level)

Fixed-Wing Aircraft Estimating Source List (cont.)

Training

MACDAR Fighter Aircraft Database, Tecolote, 1998
Advanced Fighter Aircraft Cost Model, AFCAA, 1998
Below the Line Cost Factors, AFCAA, 1998
Standard Cost Factors Handbook, NCCA, 1992
HAPCA data, NAVAIR, 1991
Development Eng. and BTL Development Cost Models, Technomics, August 1990
Kanter's Factors, Cost Factors and Estimating Relationships, Electronic Sys. Division, April 1990
Cost Factors for A/C and Missiles, Aeronautical Systems Division, May 1987

Support Equipment

MACDAR Fighter Aircraft Database, Tecolote, 1998
Advanced Fighter Aircraft Cost Model, AFCAA, 1998
Below the Line Cost Factors, AFCAA, 1998
Air Force Total Ownership Cost (AFTOC) Management Information System, MCR, 1998
Standard Cost Factors Handbook, NCCA, 1992
Development Eng. And BTL Development Cost Models, Technomics, August 1990
CER Develoment for R&D Tooling , Applied Research, March 1990
Kanter's Factors, Cost Factors and Estimating Relationships, Electronic Sys. Division, April 1990
Cost Factors for A/C and Missiles, Aeronautical Systems Division, May 1987

Spares

MACDAR Fighter Aircraft Database, Tecolote, 1998
OP-20, Obligated Spend Profiles, NAVAIR, annual
Kanter's Factors, Cost Factors and Estimating Relationships, Electronic Sys. Division, April 1990

Fixed-Wing Aircraft Estimating Source List (cont.)

O&S

Air Force Total Ownership Cost (AFTOC) Management Information System, MCR, 1998
AFI 65-503, USAF Cost Planning Factors, 1998
ABIDES
PPR Data/SDLMs (Depot Level Maintenance), NADOC, annual
OP-20, Obligated Spend Profiles, NAVAIR, annual
C3 Platform Integration Cost Model, MCR, 1997
Naval Aircraft Modification Database, MCR, 1996
Naval Fixed Wing Aircraft O&S Cost Estimating Model, Delta Research, 1990
Line Shut-Down Study, MCR, 1996 LCC Models Reference Guide, ASD, April 1983
DCA Circular 600-60-1, Cost & Planning Factors, TASC, March 1983
Modeling the Cost of Ownership for Aircraft, RAND, August 1981
Estimating Recoverable Spares Investment, RAND, August 1980
Estimating Annual O&S Cost, Watson Noah, Jan 1975
Avionics Parametric Cost Model, ASD, February 1973
Tri-Service LCC Model, EER Systems, Unknown

IV. ROTARY-WING AIRCRAFT

Richard Bishop, U.S. Army Cost and Econmic Analysis Center

Rotary-Wing Aircraft

Then-Year $ through FYDP:	**PDRR** 8% *$6B*	**EMD** 7%	**Production** 52% *$22B*
Airframe	18%	18%	34%
Propulsion	19%	8%	6%
Avionics	15%	15%	36%
Software	10%	8%	2%
Armament	4%	4%	4%
Test and Evaluation	10%	20%	1%
SE/PM	21%	21%	6%
Data	1%	1%	2%
Training	1%	4%	3%
Support Equipment	15 %	1%	2%
Spares	0%	0%	4%

Systems included in the rotary-wing aircraft category are the Comanche, SH-60R, USMC H-1, Longbow Apache, and V-22 aircraft. Cost totals shown (in billions of then-year dollars) include FY1999 to 2005 from 1997 SARs. Percentages by phase are from the Comanche estimate.

In this category, the most notable problem is Software, shown here as separate from Avionics. Airframe Composite materials and Stealth Technology are other problem areas contributing to the largely yellow areas.

O&S as 33% of total LCC seems low. It is based on a planned design to include built-in test/built-in test equipment (BIT/BITE) and fault isolation hardware and software.

Rotary-Wing Aircraft (cont.)

O&S (33%)

Mission Personnel	48%
Unit-Level Consumption	38%
Intermediate Maintenance	0%
Depot Maintenance	1%
Contractor Support	1%
Sustaining Support	11%
Indirect Support	1%

The red rating for Sustaining Support is from Software Maintenance. The other categories here are doing okay. OSMIS collects data for Unit-Level Consumption, Intermediate and Depot Maintenance. Contractor Logistic Support will be available next year and Indirect Support costs are under development in the Installation Status Reporting System.

Contributing Organizations

- Aircraft and Missile Command (AMCOM)
- U.S. Army Cost and Economic Analysis Center (USACEAC)

Data for this category were provided by Aircraft and Missile Command and the U.S. Army Cost and Economic Analysis Center.

Current & Future Outlook

- Positive
  - AFCAA-funded Avionics study
  - Comanche program manager participating in Avionics study
  - USACEAC ACDB Rotary-Wing Database
  - USACEAC OSMIS Relational Database

AFCAA has funded an Avionics cost study and the Comanche program manager is contributing to that.

OSMIS Relational Database

- Relational database now available
  - Four years of data
  - Contains FY94–97 data—FY98 March
  - FY90–93 available soon
- No CDs—online access
  - Need logon ID and password
  - www.sbcweb.calibresys.com/osmis
  - new user—register

Rotary-Wing Aircraft Estimating Source List

Airframe

ACDB Aircraft-Rotary Wing, SAIC, 1997
Rotary Wing Cost Factor Study, SAIC, 1996
Composites/Exotic Materials Database,Tecolote, 1997
Advanced Airframe Structural Materials, RAND Study, 1991
ACDB Aircraft-Rotary Wing, SAIC, 1997
Cost Considerations for LO Technology for the Comanche Helo. SAIC, 1994
Dev. of Cost Est. Methodologies for Composite Aircraft Structures and Components, LSA, 1988
CERs by WBS for Selected Helicopter Systems, CALIBER Systems, 1991

Propulsion

ACDB Aircraft-Rotary Wing, SAIC, 1997
Rotary Wing Cost Factor Study, SAIC, 1996
Aircraft Gas Turbine engine Acquisition Costs, Ketron, 1997
CERs by WBS for Selected Helicopter Systems, CALIBER Systems, 1991

Subsystems

ACDB Aircraft-Rotary Wing, SAIC, 1997
Rotary Wing Cost Factor Study, SAIC, 1996

Avionics

ACDB Aircraft-Rotary Wing, SAIC, 1997
Rotary Wing Cost Factor Study, SAIC, 1996
Parametric Approach to Est. Cost of Dev. Eng., ARI/87 TM-387, Applied Research Inc., 1987
Electronics Cost Model (TR-9505-01) Technomics , 1996
Parametric Avionics/Electronics Procurement & A/C Retrofit Cost Study/Vol. II, General Dynamics, 1984
CERs by WBS for Selected Helicopter Systems, CALIBER Systems, 1991
Organizational Options for Common Elec. Mgmt., IDA, 1992

Rotary-Wing Aircraft Estimating Source List

Software

Price S, Parametric Review of Info. for Costing and Evaluation Software Sizing Model, GE, 1997
SEER SEM, Systems Evaluation and Estimation Resources-S/W Est. Model, Galorath, 1997
Revic, Software Cost Estimating Model, AFCAA, Feb 91
SASET, Software Architecture Sizing and Estimating Tool, Martin Marietta, Apr 93
Development Support Cost Model (TR9505-04), Technomics, 1996

Armament

ACDB Aircraft-Rotary Wing, SAIC, 1997
Rotary Wing Cost Factor Study, SAIC, 1996

Test & Evaluation

ACDB Aircraft-Rotary Wing, SAIC, 1997
Rotary Wing Cost Factor Study, SAIC, 1996

SE/PM

ACDB Aircraft-Rotary Wing, SAIC, 1997
Rotary Wing Cost Factor Study, SAIC, 1996

Data

ACDB Aircraft-Rotary Wing, SAIC, 1997
Rotary Wing Cost Factor Study, SAIC, 1996
HAPCA data, NAVAIR, 1991

Training

HAPCA data, NAVAIR, 1991

Support Equipment

VAMOSC
OSMIS

Rotary-Wing Aircraft Estimating Source List

Spares

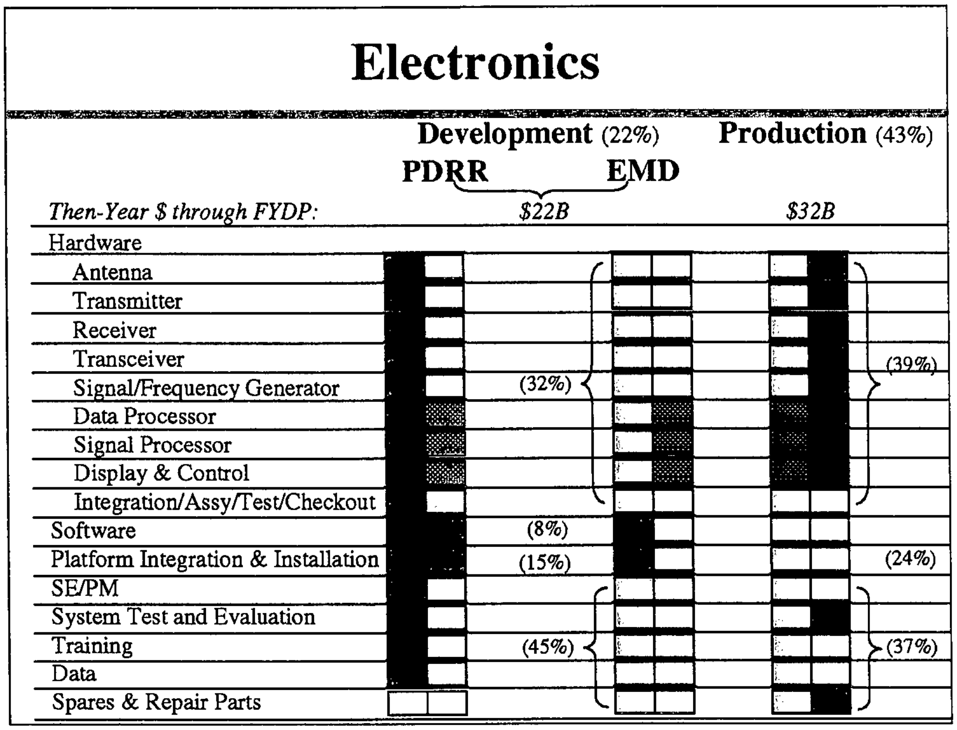
OP-20, Obligated Spend Profiles, NAVAIR, annual
CASA Cost Analysis Strategy Assessment, DSMC, 1997

O&S

VAMOSC /OSMIS
PPR Data/SDLMs (Depot Level Maintenance), NADOC, annual
OP-20, Obligated Spend Profiles, NAVAIR, annual
Tri-Service LCC Model, EER Systems, Unknown
Modeling the Cost of Ownership for Aircraft, RAND, August 1981
Estimating Annual O&S Cost, Watson Noah, January 1975
Naval Rotary Wing Aircraft O&S Cost Estimating Model, Delta Research, 1990

V. ELECTRONICS

Richard Collins, Naval Center for Cost Analysis



This slide depicts the assessment of the acquisition cost-estimating capability for electronics.

Before discussing the assessment itself, it is important to note the percentages and dollar values shown at the top of the slide. The percentages represent the phases' typical shares of LCC. On average for shipboard and airborne electronics, Development cost accounts for 22% and Production cost accounts for 43% of LCC. The dollar values, which are unrelated to the aforementioned percentages, represent the Services' budget projections for electronics across the FYDP years, fiscal years 1999 through 2005. The development value is approximately $22 billion (in then-year dollars). Since Service budget documents do not neatly aggregate the cost of electronics, this "estimate" represents a compilation of budget values for electronics systems that appear to be related to weapons (vice information technology). Specifically, this estimate is based on budget values extracted from Army, Navy/Marine Corps, and Air Force RDT&E budget back-up displays. The $22 billion total represents the sum of Demonstration and Validation (i.e., Budget Activity 4) and Engineering and Manufacturing Development (i.e., Budget Activity 5) funds, including $9 billion in D&V funds and $13 billion in EMD funds.

Though not included in the $22 billion Development total, it can reasonably be argued that $4 billion in Operational Systems Development (i.e., Budget Activity 7) funds is also weapons-related electronics "development" effort that should be included. The rationale for including these funds, which cover developmental efforts associated with *operational* electronic systems, is the fact that the cost analyst faces the same development estimating challenge regardless of whether the development estimate is for a new system or modification of an existing system.

For the same FYDP years, Production cost for electronic systems is estimated to be $32 billion. Similar to the development estimate, this estimate is based on budget values extracted from procurement budget back-up displays. The Navy portion of the total, $20 billion, includes ship-related electronics values extracted from Ship Construction, Navy (SCN) and Other Procurement, Navy (OPN) budget back-up displays and aircraft-related electronics values extracted from Aircraft Procurement, Navy (APN) budget back-up. The Air Force portion of the total, $12 billion, includes aircraft and associated ground electronics values extracted from Aircraft Procurement, Air Force (including modifications), and Other Procurement, Air Force budget back-up.

Unlike the Development estimate, this estimate includes Navy and Air Force values only. Time constraints precluded inclusion of Marine Corps and Army electronics. As a result, the $32 billion production value is understated relative to the development value.

It is also important to note the percentages associated with the cost elements. These percentages, which sum to 100% for a given life-cycle phase and account for both contractor and government in-house costs, indicate a cost element's (or cost element grouping's) typical share of phase total cost. The intent of these percentages is to focus our attention on the significant, from a dollar perspective, red and red-yellow cost elements.

Now for the assessment. In general, this year's assessment of DoD's capability to estimate electronics Development and Production cost is essentially the same story presented at the last DoDCAS in February 1998. Similar to last year, the assessment tends to mirror the expectations discussed by Dr. Balut. With a couple of notable exceptions, PDRR is rated red-yellow, EMD is rated yellow, and Production is rated yellow-green. The exceptions, Software and Platform Integration and Installation, are addressed below.

- Software: A number of factors contributed to the nearly 100% red rating. First, with respect to data, the quantity and quality of development and maintenance data are viewed as problematic. Second, with respect to methodology, the heavy reliance of existing models (public domain and commercial) on subjective input is viewed as problematic. Third, with respect

to technical definition, the uncertainty in sizing estimates is viewed as problematic.

• Platform Integration and Installation: The rationale for the assessment is quite simple: lack of understanding of the explanatory variables, no compilation of data, and no methodology. With respect to the data void, cost reports typically do not provide the visibility required to isolate these costs.

There are some differences between this and last year's assessment. These differences are highlighted in the slide with cross-hatching. The most notable change is the worsening of the assessment for Processor and Display and Control hardware. Last year, the assessment for these elements was better than expected. The relatively favorable assessment was directly related to the increasing application of commercial off-the-shelf (COTS) equipment for these functions. Specifically, with respect to recurring hardware costs, availability of COTS price information and knowledge of COTS price trends for these types of equipment were the bases for the positive perspective. This year, many of the organizations contributing to the assessment believed that the past year had taught them that COTS estimation, both in the Development and Production phases, is a tremendous challenge that cannot be addressed with existing databases and estimating methodologies.

Electronics (cont.)

		O&S (35%)
Mission Personnel		(29%)
Unit-Level Consumption	Spares/Repair Parts(11%)	(13%)
Intermediate Maintenance		(< 1%)
Depot Maintenance		(7%)
Contractor Support		(included above)
Sustaining Support	Modification Kits (25%) Engineering Support (11%) Software Maintenance (5%)	(41%)
Indirect Support	Training (9%) PCS (1%)	(10%)

This slide depicts our assessment of the O&S cost-estimating capability in electronics. The assessment covers each of the O&S cost elements included in the *Operating and Support Cost-Estimating Guide* published by OSD CAIG in May 1992.

On average for shipboard and airborne electronics, O&S cost accounts for 35% of LCC. Unlike the previous slide for the acquisition phases, this slide does not include the FYDP dollar values. The nature of budget back-up information does not lend itself to a meaningful electronics O&S budget value for the FYDP. Similar to the previous slide, percentages depicting each cost element's typical share of total O&S phase cost is shown. In addition, for selected cost elements, percentages are provided for major subelements.

In general, this year's assessment of DoD's capability to estimate electronics O&S cost is essentially the same story presented at the last DoDCAS in February 1998. Similar to last year, the assessment tends to mirror the expectation discussed by Dr. Balut. With a couple of notable exceptions, O&S is rated yellow. The exceptions, Mission Personnel and Sustaining Support, are addressed below.

- Mission Personnel: This element is rated green because estimation of the pay and allowances (P&A) for electronics operators and maintainers is a rather straightforward exercise driven by quantity and average P&A.

• Sustaining Support: This element includes three major components—modification kits, engineering support, and software maintenance. The red-yellow rating (i.e., worse than the expected yellow) is attributed to database and methodology weaknesses related to software maintenance and, to a lesser extent, engineering support.

There is only one difference between this and last year's assessment. This difference, highlighted with cross-hatching, is the worsening of the assessment for indirect cost. Based on OSD and Service initiatives to understand and reduce the O&S costs (direct *and* indirect) of new and fielded systems, cost analysts have devoted more attention over the past year to indirect costs. Unfortunately, in doing so, analysts have identified associated database and methodology voids.

Contributing Organizations

- Air Force Cost Analysis Agency (AFCAA)
- Air Force Electronics Systems Center (ESC/FMC)
- Army Communications and Electronics Command (CECOM)
- Naval Air Systems Command (NAVAIR)
- Naval Sea Systems Command (NAVSEA)
- Naval Surface Warfare Center (NSWC)/Dahlgren Division
- Naval Center for Cost Analysis (NCCA)
- OSD Cost Analysis Improvement Group (CAIG)
- Ballistic Missile Defense Organization (BMDO)
- Technomics, Inc.
- Tecolote Research, Inc.

The assessment is based on input from representatives from the nine DoD and two private sector organizations listed here.

Electronics Studies: Software & Integration/Installation

Software

- SMC Software Database (SMC/MCR)
- Software Development Cost/Technical Database (NCCA/MCR)
- Software Development Estimating Handbook - Phase One (NCCA)
- Software Maintenance Cost/Technical Database & Methodology (NCCA/Technomics)
- Software Cost Estimating (SSDC/SAIC)
- Improved Software Cost Report Processes for Weapon Systems (PA&E/IDA)

Platform Integration & Installation

- PRICE Model Calibration Studies for F-15 & B-1 Integration (ASC/PRICE)
- Model for Integrating Cost with Operational Effectiveness (ASC/Technomics)
- C^3 Platform Integration Database (AFCAA/MCR)

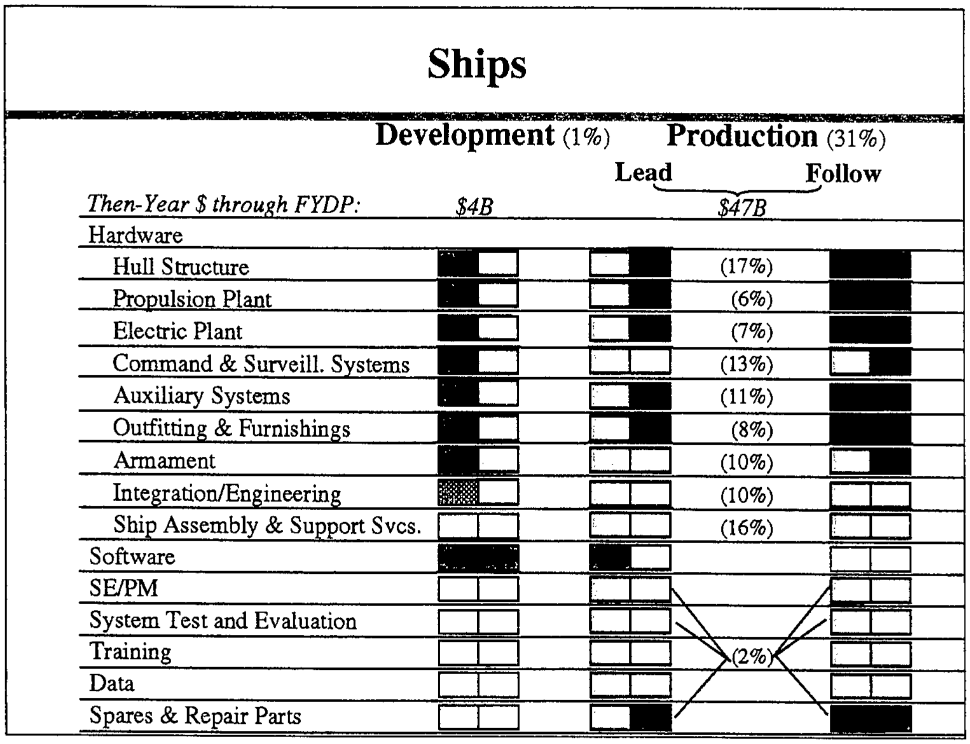
This and the next slide list some recently completed and ongoing electronics studies that address the red and yellow elements. The sponsoring and performing organizations are shown in parentheses (sponsor/performer). It remains to be seen whether the results of these studies will translate into improved cost-estimating capability, particularly in the most problematic areas—Software and Platform Integration and Installation.

Electronics Studies: Others

- Case Study, APG-63 V(1) Radar, F-15 Case Study (ASC)
- Avionics Nonrecurring Design Cost and Development Time (NAVAIR/MCR)
- Development CERs (BMDO/MCR)
- Improved Methodologies for Estimating Development Costs (PA&E/LMI)
- Avionics Systems Data Collection (AFCAA/Tecolote)
- Communications and Electronics Cost Database/Methodology (CEAC/Technomics)
- Electronics Cost/Technical Database (NCCA/Tecolote)
- Avionics Support Cost Factors Update (ASC)
- Transmit/Receive Module Model Update (NCCA/Tecolote)
- Incentive Models for Cost Progress (PA&E/LMI)
- Parametric O&S CERs for Shipboard Electronics (ONR/NCCA and Tecolote)

VI. SHIPS

Richard Collins, Naval Center for Cost Analysis



This slide depicts the assessment of our cost-estimating capability for ship acquisition.

Note that the format of this slide differs from others like it. Specifically, there are no separate columns for PDRR and EMD and there are two production columns, one for the lead (or first) ship of a class and the other for the follow-on (or subsequent) ships of the class. This format is consistent with the fact that the nature of ships acquisition differs significantly from that for other weapon systems.

Before addressing the assessment itself, it is important to explain the percentages and dollar values shown at the top of the slide. The percentages represent the life cycle phases' typical share of LCC. On average for ships, Development cost accounts for 1% and Production cost accounts for 31% of LCC. The development percentage for ships is significantly lower than the comparable percentages for other weapon commodities. This low percentage is due largely to the fact that typical ship procurement cost (i.e., average unit cost of hundreds of millions to several billion dollars) and O&S cost (i.e., average annual unit cost of tens of millions to over $100 million for 30 to 40 years each) far outweighs typical ship development cost.

This low percentage is also partially attributable to the scope of development activities typically funded and managed (or more importantly, not funded/managed) by the Ship Acquisition Program Manager (SHAPM). For example, this phase does not include development of prototype *ships* and generally does not include development of prototype *systems* [i.e., hull, mechanical and electrical (HM&E), electronics and ordnance]. In the case of the ship, which is essentially a platform for the various systems, Development-funded effort includes feasibility studies, preliminary design, and contract design. In the case of systems, Development-funded effort includes platform integration studies. In most cases (the Aegis-class surface ship weapon system and Virginia-class submarine combat system are exceptions), development of prototype systems are funded/managed by the program managers for the respective systems (known as the Participating Manager or PARM), not the SHAPM. This is a result of the Navy's philosophy that ship systems should generally be designed for application to more than one platform type (i.e., ship class).

The Production phase's share of LCC, 31%, represents the sum of the cost for the lead and follow ships. The lead ship column depicts the Navy's ability to estimate the cost to design and construct the lead ship, which is essentially a procurement-funded, fielded "prototype." The follow ship column addresses the Navy's ability to estimate the predominantly recurring costs to construct the subsequent ships of the class. From the perspective of estimating capability, the principal difference between these columns is the challenge of estimating the nonrecurring costs associated with the lead ship.

The dollar values, which are unrelated to the aforementioned percentages, represent the Navy's budget projections for ships across the FYDP years, FY 1999 through 2005. The development value is approximately $4 billion (then-year dollars). This estimate is based on budget values extracted from Navy RDT&E budget back-up displays. The $4 billion total represents the sum of Demonstration and Validation (i.e., Budget Activity 4) and Engineering and Manufacturing Development (i.e., Budget Activity 5) funds, including $1.2 billion in D&V funds and $2.8 billion in EMD funds. Consistent with the previous discussion regarding the scope of ship development activities, these values reflect RDT&E effort associated with specific ship classes or technologies benefiting one or more ship classes. Accordingly, they do not include RDT&E funds for development of ship systems managed by PARMs. For the same FYDP years, ship production cost is estimated to be $47 billion. Similar to the development estimate, this estimate is based on budget values extracted from procurement budget back-up displays, specifically Ship Construction, Navy (SCN) displays. These budget values include the total cost of the platform, including detailed design and all systems installed on it.

Now for the assessment. In general, this year's assessment of DoD's capability to estimate ship development and production cost is essentially the same story presented at the last DoDCAS in February 1998. With a few exceptions, the assessment generally mirrors the expectations discussed by Dr. Balut. PDRR/EMD is rated red-yellow or yellow. Lead ship production, which includes a significant degree of nonrecurring effort, is primarily yellow. Follow ship production, which includes a less significant degree of nonrecurring effort, differs from the expected yellow-green; it is principally a mix of either yellow or green. A few comments are in order with respect to areas where the assessment differed from the expectations discussed by Dr. Balut. First, I will address the significant areas where the assessment was worse than expected.

- <u>Software</u>: Several factors contributed to the nearly 100% red rating. First, with respect to data, both the quantity and quality of development and maintenance data are viewed as problematic. Second, with respect to methodology, the heavy reliance of existing models (public domain and commercial) on subjective input is viewed as problematic. Third, with respect to technical definition, the uncertainty in sizing estimates is viewed as problematic.

- <u>Integration/Engineering, Ship Assembly & Support Services, SE/PM, System Test and Evaluation, Training, and Data</u>: The rationale for the assessment is simple—lack of understanding of the explanatory variables resulting in little or no meaningful methodology.

Here I address the significant areas where the assessment was better than expected.

- <u>Hardware, Spares and Repair Parts</u>: Hull, propulsion, electric, auxiliary and outfitting and furnishings are viewed as less complex subsystems that are better understood than the more complex electronics-oriented command, surveillance, and armament subsystems. This same rationale applies to the spares and repair parts associated with these subsystems.

There is only one difference between this and last year's assessment. This difference, highlighted with cross-hatching, is the worsening in the assessment of Development phase Integration/Engineering. The rationale for this change was not to reflect a degradation in capabilities over the past year, but rather to correct what was deemed an unrealistic assessment.

Ships

		O&S (68%)
Mission Personnel		(44%)
Unit-Level Consumption	Spares/Repair Parts(11%) POL(6%)	(16%)
Intermediate Maintenance		(<1%)
Depot Maintenance		(30%)
Contractor Support		(included above)
Sustaining Support		(7%)
Indirect Support		(3%)

This slide depicts the assessment of our cost-estimating capability for ship O&S. The assessment is based on input from the four organizations listed on the next slide. The assessment covers each of the O&S cost elements included in the *Operating and Support Cost-Estimating Guide* published by the OSD CAIG in May 1992. On average for a variety of conventionally and nuclear-powered ship classes, O&S cost accounts for 68% of LCC. Unlike the previous slide for the acquisition phases, this slide does not include the FYDP dollar values. The nature of budget back-up information does not lend itself to a meaningful ship O&S budget value for the FYDP. In general, this year's assessment of DoD's capability to estimate electronics O&S cost is essentially the same story presented at the last DoDCAS in February 1998. Similar to last year, the assessment tends to mirror the expectation discussed by Dr. Balut. With a couple of notable exceptions, O&S is rated yellow. The exceptions, Mission Personnel and Sustaining Support, are addressed below.

- Mission Personnel: This element is rated green because estimation of the pay and allowances (P&A) for electronics operators and maintainers is a straightforward exercise driven by quantity and average P&A.

- Sustaining Support: This element includes the following three major components: modification kits, engineering support, and software maintenance. The red-yellow rating (i.e., worse than the expected yellow) is attributed to database and methodology weaknesses related to software maintenance and, to a lesser extent, engineering support.

There is only one difference between this and last year's assessment. This difference, highlighted with cross-hatching, is the worsening of the assessment for indirect cost. Based on OSD and Service initiatives to understand and reduce the O&S costs (direct *and* indirect) of new and fielded systems, cost analysts have devoted more attention to indirect costs over the past year. Unfortunately, in doing so, they have identified associated database and methodology voids.

Contributing Organizations

- Naval Sea Systems Command (NAVSEA)
- Naval Surface Warfare Center (NSWC)/Carderock Division
- Naval Center for Cost Analysis (NCCA)
- OSD Cost Analysis Improvement Group (CAIG)

The assessment is based on input from representatives of the four DoD organizations listed here.

Ship Studies

- AACEI Cost Model for Aircraft Carriers (NAVSEA/Tecolote)
- Private Shipbuilder Overhead Costs (NAVSEA and PA&E/IDA)
- Aircraft Carrier Performance-Based Procurement Model (NAVSEA/NSWC Carderock Division)
- Surface Combatant Performance-Based Procurement Model (NAVSEA/NSWC Carderock Division)
- Product-Oriented Design and Construction (PODAC) Cost Model (NAVSEA/NSWC Carderock Division, Shipyards, University of Michigan, and SPAR)
- Ship Operating and Support Cost Analysis Model (OSCAM) for Ships and Ship Systems (NCCA/U.K. MOD/HVR)

This slide lists some recently completed and ongoing ship studies. The sponsoring and performing organizations are shown in parentheses (sponsor/performer). It remains to be seen whether the results of these studies will translate into improved cost-estimating capability. In addition to these studies, the electronics studies that relate to the problem areas of Software and Platform Integration and Installation are also relevant to ships.

VII. MISSILES

Richard Bishop, U.S. Army Cost and Economic Analysis Center

Missiles

	PDRR (14%)	EMD (13%)	Production (33%)
Then-Year $ through FYDP:	*$3B*		*$27B*
Air Vehicle			
Propulsion	2%	6%	9%
Payload	0%	1%	2%
Airframe	0%	1%	2%
Guidance and Control	6%	14%	23%
Integration, Assembly, & Test/Checkout	2%	4%	7%
Command and Launch			
Surveillance, ID & Track Sensor	32%	11%	24%
Launch & Guidance Control	3%	5%	4%
Communications	0%	1%	2%
Launcher Equipment	1%	2%	2%
SE/PM	25%	31%	17%
System Test & Evaluation	15%	14%	3%
Training	0%	2%	2%
Software	12%	7%	
Peculiar/ Common Support Equipment	0%	0%	1%
Initial Spares & Repair Parts	1%	0%	2%

Overall, our estimating capability for missiles is fair to good, but there are problems. Many of the studies are aging and we need data for new technology and materials.

Airframe is red because of new methods and materials and old studies and CERs. Launcher Equipment is also red in PDRR and EMD.

The surprises are the red in Propulsion and Airframe. We continue to need CERs for estimating the cost of missile propulsion systems and structures; our methodology for propulsion is aging given the new Gel technology, and needs to be updated.

Seekers were a big unknown, but we have studied them and now have some actual costs for imaging infrared. Also millimeter wave seekers are not the mystery they once were, but still more data are needed.

Although little (or no) additional known data exists for divert attitude control systems, there is little confidence using current methods. It is suggested that some work be accomplished in this area as soon as practicable.

Missiles

	O&S (39%)
Mission Personnel	8%
Unit-Level Consumption	21%
Intermediate Maintenance	12%
Depot Maintenance	11%
Contractor Support	4%
Sustaining Support	29%
Indirect Support	15%

Improvements: Army OSMIS has developed a Relational Data Base to allow analysts to search for data points to assist in developing O&S methodologies. Analogies are based on past systems. However, current O&S relationships are not sensitive to mean time between failures (MTBF), built in test equipment (BITE), and other factors influenced by design. CAIV and other design-to-cost efforts performed in RDT&E will not likely be properly costed in O&S.

Budget dollars shown (in billions of then-year dollars) are from 1997 SARs for FYDP fiscal years 1999 to 2005.

Systems included are ATACMS/APAM, ATACMS/BAT, MLRS, Javelin, Longbow, Hellfire, Patriot PAC-3, Tomahawk, Trident, Standard Missile, AIM-9X, JSOW, Navy TBMD, AMRAAM, Minuteman, and JASSM.

Contributing Organizations

- Army Cost and Economic Analysis Center (USACEAC)
- Army Aircraft and Missile Command (AMCOM)
- Army Strategic Missile Defense Command (SMDC)
- Air Force Cost Analysis Agency (AFCAA)
- Naval Center for Cost Analysis (NCCA)
- Naval Air Systems Command (NAVAIR)
- Tecolote Research, Inc.

The seven organizations listed here responded to our query.

OSMIS Relational Database

- Relational database now available
  - Four years of data
  - Contains FY94–97 data—FY98 March
  - FY90–93 available soon
- No CDs—online access
  - Need logon ID and password
  - www.sbcweb.calibresys.com/osmis
  - new user—register

Current & Future Outlook

- Positive
  - NCCA has developed a PDRR Phase II CER
  - AFCAA-funded Missile CER study, ACDB Database
  - CEAC OSMIS Relational Database, ACDB Database
- Negative
  - Several program managers received waivers for CCDRs

On the positive side we have NCCA's PDRR Phase II CER, AFCAA's funding of the Missile CER study, and the OSMIS Relational Database.

On the negative side, several PMs have, in effect, received waivers for production CCDRs.

Missile Estimating Source List

EMD PHASE

General (applies to all WBS elements):

RAM Production Model

Theater Ballistic Missile Defense (TBMD) Model, E. Waller, Technomics, Inc., September 1997

WBS: Hardware

The Relationship Between Tactical Missile Development Unit Cost and Production Unit Cost, Science Applications International Corporation, September 1990 and November 1997, prepared for NCCA and NAVAIR 4.2.

Analysis of the Relationship Between Development and Production Costs and Comparisons with Other Related Step-Up/Step-Down Studies, Mr. Hardina and Dr. D. Nussbaum, Naval Center for Cost Analysis, January 1994

WBS: G&C

Tactical IR Sensor Cost Model I, Technomics, February 1991, prepared for U.S. Army Strategic Defense Command

Tactical IR Sensor Cost Model II, Technomics, February 1994, prepared for U.S. Army Cost Analysis and Economic Analysis Center

WBS: Airborne Test Equipment

Interceptor Guidance Electronics Cost Estimating Relationship, Volume I, J. McDowell and D. Sallo, Tecolote Research, Inc., February 1993

WBS: Systems Engineering/Program Management

Tactical Missile Development Costs, Science Applications International Corporation, May 1987, prepared for NCCA

RDTE IV--Tactical Missile RDT&E Cost Model, D. C. Morrison and R. C. Namu, Tecolote Research, Inc., November 1990, prepared for Naval Weapons Center at China Lake, California, Contract No. N60530-88-D-0129

Tactical Missile Systems Development Costs, CDR H. B. Everage and Mr. V. Reisenleiter, Naval Center for Cost Analysis, 1991

Missile Estimating Source List

WBS: Systems Test & Evaluation

Tactical Missile Development Costs, Science Applications International Corporation, May 1987, prepared for NCCA

RDTE IV- Tactical Missile RDT&E Cost Model, Tecolote Research, Inc, D.C. Morrison and R. C. Namu, November 1990, prepared for Naval Weapons Center at China Lake, California, Contract No. N60530-88-D-0129

Tactical Missile Systems Development Costs, CDR H. B. Everage and Mr.V. Reisenleiter, Naval Center for Cost Analysis, 1991

Joint Missile/Munitions Database, ACDB, Tecolote Research, Inc. 1998

Dev Eng & Below The Line Dev Models, Technomics, Inc., August 1990 (NR)

Radar Production Cost Model, OSD/PA&E, May 1988, (R)

Miscellaneous Sources and CER Memos, Varied Authors / Dates

Cost Factor Study Report (Kanter's Factors), Tecolote, August 1989

Program Level Cost Factors for Missile Programs in Production, ARI, June 1990

Tactical Missile Systems Development Costs, Navy Cost Center, September 1992

Missile Cost Data Book, Tecolote, November 1984

Test and Evaluation (T&E) Handbook/Guide, ASDC (now SMDC), Tecolote Research, Inc., 1994

WBS: Data

Tactical Missile Development Costs, Science Applications International Corporation, May 1987, prepared for NCCA

RDTE IV- Tactical Missile RDT&E Cost Model, Tecolote Research Inc, D. C. Morrison and R. C. Namu, November 1990, prepared for Naval Weapons Center at China Lake, California, Contract No. N60530-88-D-0129

Tactical Missile Systems Development Costs, CDR H. B. Everage and Mr. V. Reisenleiter, Naval Center for Cost Analysis, 1991.

WBS: Software

Software Development Phase One Estimating Handbook, C. Cummings, et al., Naval Center for Cost Analysis, 1997

Missile Estimating Source List

Cost Estimating Relationships for High Value Electronic/Electro-Optical/Electro-Mechanical Components of Tactical Missiles, Technomics, Inc, December 1993, prepared for NCA and Naval Surface Warfare Center

Tactical Missile Guidance and Control Cost Estimating Relationships, Science Applications International Corporation, April 1989

Joint Missile/Munitions Database, ACDB, Tecolote Research Inc. 1998

Seeker Study, AFCAA, 1998

Dev Eng & Below The Line Dev Models, Technomics Inc., August 1990 (NR)

Electronic Box & Electro-Optical Equip Cost Analysis Briefing, Tecolote, September 1986 (R)

Radar Production Cost Model, OSD/PA&E, May 1988, (R)

Black Box Estimators (BBEST) Electronics Cost Model, Tecolote, June 1989 (NR, R)

Prototype to Production Step-Down Model, MCR, July 1987

Dev to Prod and Rate in Seeker Radars, Tecolote, May 1986

HARM Guidance Engineering Build-up Cost Model, Technomics, March 1987

Inter-Service Missile Info System, SAIC, September 1990 (R)

CER for H-Value Electronic E-O Comp of Tactical Missiles, Technomics, December 1993 (R)

Tactical IR Sensor Cost Model, Technomics, February 1991 (R)

Cost Methods for IR Seeker Windows and Frame Cooling Tech., Tecolote, December 1991 (R)

Avionics IR Sensor/Laser Cost Model, Technomics, September 1992 (R)

CER Development for IR Seeker, Applied, May 1990 (R)

WBS: Tooling and Test Equipment

Joint Missile/Munitions Database, ACDB, Tecolote Research Inc., 1998

Dev Eng & Below The Line Dev Models, Technomics Inc., August 1990 (NR)

CER Develop for Tactical Missile Special Tooling and Test Equipment, SAIC, February 1986 (NR)

Munitions ST/STE Cost Model Study, General Research, May 1983 (NR, R)

Tooling & Test Equipment Cost Methodology, General Research, December 82 (NR, R)

Electronic Box & Electro-Optical Equip Cost Analysis Briefing, Tecolote, September 1986 (R)

Missile Estimating Source List

Tactical Missile Systems Development Costs, Navy Cost Center, September 1992

Missile Cost Data Book, Tecolote, November 1984

WBS: Systems Engineering /Program Management

Naval Weapon Center (NWC) Modular Missile Cost Model, by Tecolote Research Inc, November 1990, prepared for the Naval Weapon Center at China Lake

Missile System Non-Recurring and Recurring Procurement Support Cost Models Vol. I and II, by Management Consulting and Research, Inc., July 1987

Competition Impacts on Systems Engineering/Program Management Cost Factors in Air Force and Navy Missile Programs, by Tecolote Research, Inc, March 1993

Joint Missile/Munitions Database, ACDB, Tecolote Research Inc. 1998

AFCAA, Missile CER Study, 1999

Cost Factors for A/C and Missiles, Aeronautical Systems Division, May 1987

Dev Eng & Below The Line Dev Models, Technomics Inc., August 1990 (NR)

CER for Tactical Missiles SEPM in Production, ASD/ACCI, August 1990 (R)

Algorithms to Predict SE/PM and E&A for AMRAAM ICA, AD/ACCE, May 1987 (R)

Cost Factor Study Report, Tecolote, August 1989

Program Level Cost Factors for Missile Program in Production, ARI, June 1990

Missile Guidance Systems CER Development, General Research, September 1985

Cost Factor Study Report (Kanter's Factor), Tecolote, August 1989

Missile Cost Data Book, Tecolote, November 1984

A Cost Estimating Relationship for Tactical Missiles Systems Engineering Program Management in Production, Thomas Morey, 1990

An Estimator for Government Systems Engineering & Program Management in Tactical Missile Programs, Naval Center for Cost Analysis, Technical Report # 005-92, Vern Reisenleiter, August 1992

Missile Estimating Source List

WBS: Training

Joint Missile/Munitions Database, ACDB, Tecolote Research Inc. 1998
AFCAA, Missile CER Study, 1999
Cost Factors for A/C and Missiles, Aeronautical Systems Division, May 87
Radar Production Cost Model, OSD/PA&E, May 1988 (R)
Program Level Cost Factors for Missile Programs in Production, ARI, June 1990
CER Development for R&D Missile Training Programs, ARI, March 1990
Missile Cost Data Book, Tecolote, November 1984

WBS: Data

Joint Missile/Munitions Database, ACDB, Tecolote Research Inc. 1998
AFCAA, Missile CER Study, 1999
Cost Factors for A/C and Missiles, Aeronautical Systems Division, May 1987
Dev Eng & Below The Line Dev Models, Technomics Inc., August 1990 (NR)
Radar Production Cost Model, OSD/PA&E, May 1988, (R)
Cost Factor Study Report (Kanter's Factors), Tecolote, August 1989
Program Level Cost Factors for Missile Programs in Production, ARI, June 1990 (R)
Tactical Missile Systems Development Costs, Navy Cost Center, September 1992 (NR)
Missile Cost Data Book, Tecolote, November 1984
An Estimator for Data Tactical Missile Programs, Naval Center for Cost Analysis Technical Report # 008-92, J. Eggleston, August 1992

WBS: Peculiar & Common Support Equipment

Joint Missile/Munitions Database, ACDB, Tecolote Research Inc., 1998
AFCAA, Missile CER Study, 1999
Cost Factors for A/C and Missiles, Aeronautical Systems Division, May 1987
Cost Factor Study Report (Kanter's Factors), Tecolote, August 1989
Program Level Cost Factors for Missile Programs in Production, ARI, June 1990 (R)
Tactical Missile Systems Development Costs, Navy Cost Center, September 1992

Missile Estimating Source List

WBS: System Test & Evaluation

Naval Weapon Center (NWC) Modular Missile Cost Model, Tecolote Research Inc, November 1990, prepared for the Naval Weapon Center at China Lake
Missile System Non-Recurring and Recurring Procurement Support Cost Models VOL I and II, Management Consulting and Research, Inc., July 1987

WBS: Initial Spares

Naval Weapon Center (NWC) Modular Missile Cost Model, Tecolote Research Inc, November 1990, prepared for the Naval Weapon Center at China Lake
Missile System Non-Recurring and Recurring Procurement Support Cost Models VOL I and II, Management Consulting and Research, Inc., July 1987

WBS: Industrial Facilities

Construction Cost Estimating Data Book, Applied Research Inc., June 1988, prepared for Strategic Defense Initiative Organization

O&S PHASE

WBS (Applies to most elements within the O&S phase)

Navy Surface-Launched Missile Operating and Support Cost Model, Administrative Sciences Corporation, January 1989, prepared for NCCA
Navy Air-Launched Missiles Operations and Support Cost Model, Administrative Sciences Corporation, January 1989, prepared for NCCA
COTS Electronic Technology Assessment/Refresh Cost Model, M. Roby, Naval Surface Warfare Center, Crane Division
Army VAMOSC, Operating and Support Cost Management Information System (OSMIS), FY96 Cost Reports, Volume 3 Artillery/Missile Systems
Army OSMIS Online Relational Database
VAMOSC
ABIDES
USAF and Planning Factors AF65-503, AFCAA, October 1989

Missile Estimating Source List

Cost Factors and Estimating Relationships (Kanter's Factor), ESD, April 1990
USASDC Common Cost Estimating Methodology, AFCAA, March 1992
Space Systems Operations and Support (SSOS) Cost Model, Tecolote, September 1991
Tri-Service Life Cycle Cost Model, EER, 1991
PPR Data / SDLMs (Depot Level Maintenance), NADOC, annual
OP-20, Obligated Spend Profiles, NAVAIR, annual
Parametric CERs for Tactical Missile Support Cost Elements, System Consultants Inc, J. P. Cyr, and R. E. Bently for Chief of Naval Operations (CNO, OP96-D), April 1990
Fleet Support Costs for Tactical Missiles, Naval Center for Cost Analysis Technical Report # 009-92, E. Frye, August 1992
Parametric Ship Systems Initial Support Cost Model, SAIC, for Naval Center for Cost Analysis, March 1989

VIII. SURFACE VEHICLE SYSTEMS

Richard Bishop, U.S. Army Cost And Economic Analysis Center

Surface Vehicle Systems

Then-Year $ through FYDP:	**PDRR** 4%	*$3B*	**EMD** 5%	**Production** 38%	*$9B*
Hull Platform/Suspension/Turret	□□	1%	□□	□□	8%
Power Package/Drive Train	□□	3%	□□	□□	16%
Armament	□□	1%	□□	□■	8%
Automatic Loader	■■	2%	■■	■□	13%
Fire Control	□□	1%	□□	□□	4%
Special Equipment	■□	2%	■□	□■	18%
Nuclear, Biological, Chemical	□□	1%	□□	□□	8%
Communications—Navigation	□□	0%	□□	□□	4%
Integration, Assembly & Test/Checkout	■□	1%	■□	■□	5%
SE/PM	■■	25%	■■	■■	2%
System Test & Evaluation	□□	12%	□□	□□	1%
Training	■■	1%	□□	□□	0%
Data	□□	3%	□□	□□	1%
Initial Spares & Repair Parts	■■	0%	■■	■■	3%
Other	□□	46%	□□	□□	8%

Special Equipment is red in all phases except O&S; we have no data for these subsystems. Automatic Loader is also red; there are few previous Army systems and we have no data.

Integration, Assembly and Test lacks the appropriate level of detail and there is no confidence in parametric methods.

Budget dollars shown (in billions of then-year dollars) are from 1997 SARs. Systems included are Crusader, Abrams, Bradley, the Family of Tactical Vehicles (FMTV), and Advanced Amphibious Assault Vehicle (AAAV).

Surface Vehicle Systems

O&S (54%)

Mission Personnel	58%
Unit-Level Consumption	24%
Intermediate Maintenance	0%
Depot Maintenance	1%
Contractor Support	0%
Sustaining Support	10%
Indirect Support	6%

Contributing Organizations

- U.S. Army Tank-Automotive and Armaments Command (USATACOM)
- U.S. Army Cost and Economic Analysis Center (USACEAC)

Data are from the U.S. Army Tank-Automotive and Armaments Command and Cost and Economic Analysis Center. The overall comment from USATACOM was: "We have data and methods except for materials that push the state of the art."

Current Projects
Wheel & Track Vehicle Database

- Background
  - One of four databases sponsored by USACEAC that provide a standard data format for cost and technical data for each of these four commodities
  - Part of the Automated Cost Estimating Integrated Tools (ACEIT) software suite
- Users
  - U.S. Army Cost and Economic Analysis Center
  - U.S. Army Tank-Automotive and Armaments Command
- Status
  - Fielded in February/March 1998
  - Content and structure are being expanded and improved through interaction with the user groups

There have been no new studies since last year.

Database Fielding

- Schedule
  - USACEAC on February 27, 1998 (7 attendees)
  - USATACOM on March 11–12, 1998 (29 attendees)
- Training Syllabus
  - Executive overview of the database
  - Hands-on familiarization
    - Introduction to the features of the software
    - Description of the cost and technical information contained
    - Demonstration of statistical analysis of the data using ACEIT/CO$TAT
  - Materials provided to the on-site users
    - Executive Overview of the Wheel and Track Vehicle Database
    - Database Reference List
    - Software Training Guide
    - Electronic copy of the database

OSMIS Relational Database

- Relational database now available
  - Four years of data
  - Contains FY94–97 data—FY98 March
  - FY90–93 available soon
- No CDs—online access
  - Need logon ID and password
  - www.sbcweb.calibresys.com/osmis
  - new user—register

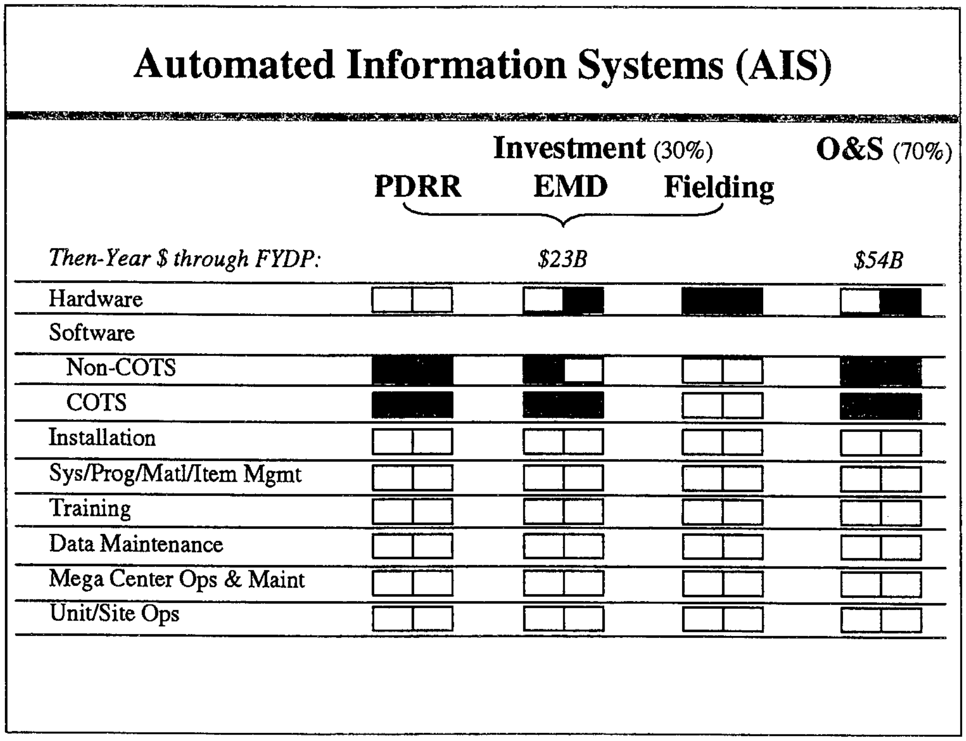
The OSMIS Relational Database is a new, improved system for search and retrieval of actual O&S cost data to support cost estimators.

Current & Future Outlook

- Positive
  - USACEAC OSMIS Relational Database,
  - ACDB Combat Vehicle Database
  - USATACOM Performance Assessment Analysis Model (PAAM)
- Negative
  - Several program managers not supporting EVM system

IX. AUTOMATED INFORMATION SYSTEMS

Richard Collins, Naval Center for Cost Analysis



This slide depicts the assessment of our cost-estimating capability for automated information systems (AIS). AIS was not addressed by this panel last year.

Before addressing the assessment itself, some background regarding the AIS estimating environment is useful.

- AIS programs are primarily software development in nature. Specifically, these programs involve developmental software and customization of COTS software products. In addition, these programs involve integration of non-COTS and COTS software, which is particularly problematic.

- AIS programs leverage COTS hardware to the maximum extent possible, thereby requiring little or no hardware development effort.

- AIS programs generally require minimal cost data reporting by the contractor. Specifically, there is some data like that from the Cost Performance Report (CPR) and no data like that from Contractor Cost Data Reporting (CCDR).

The COTS hardware/software-intensive nature of AIS programs results in dynamic technical baselines and Cost Analysis Requirements Descriptions (CARDs). That is, rapid technology advancement translates directly into rapid technical baseline obsolescence.

Before discussing the assessment, it is important to note the percentages and dollar values shown at the top of the slide. The percentages represent the life cycle phases' typical share of LCC. On average for Army, Navy, Air Force, and OSD Information Technology (IT) programs, Investment cost (i.e., the equivalent of Development plus Production cost in the weapon system world) accounts for 30% and O&S cost accounts for 70% of typical AIS LCC. The dollar values represent the Services' and OSD's budget projections for all IT programs across the FYDP, fiscal years 1999 through 2005. The values for investment and O&S are $23 billion and $54 billion, respectively. These values represent a compilation of projections extracted from RDT&E, Procurement, and Operations and Maintenance (O&M) budget back-up.

Now for the assessment. In general, the assessment is consistent with my earlier comments regarding the AIS estimating environment. The slide indicates that the AIS cost community has a sense of confidence with respect to hardware cost estimating and significant needs with respect to many of the other cost elements, especially, and not surprisingly, Software. Some specifics follow.

- <u>Hardware</u>—This element is rated green or yellow-green because there is virtually no development estimating required and procurement estimates are based on catalog or standard contract prices for non-tactical IT equipment.

- <u>Software</u>—Similar to the software assessment provided for electronics and ships, a number of factors contributed to the nearly 100% red rating. First, with respect to data, the quantity and quality of development and maintenance data are viewed as problematic. There is little or no historical data for estimating COTS software customization and integration. Similarly, there is a paucity of historical data for estimating non-COTS software development and maintenance. Second, with respect to methodology, the heavy reliance of existing models (public domain and commercial) on subjective input is viewed as problematic. Third, with respect to technical definition, the uncertainty in sizing estimates is viewed as problematic.

- <u>Other Elements</u>—In general, the yellow rating is attributed to a lack of historical data and associated estimating methodology.

The AIS estimating community is hopeful that an evolving DoD initiative to extend the CCDR requirement to AIS programs will facilitate the collection of reliable cost data and eventual development of cost-estimating methodologies based on these data.

Contributing Organizations

- U.S. Army Cost and Economic Analysis Center (USACEAC)
- Naval Center for Cost Analysis (NCCA)
- Air Force Cost Analysis Agency (AFCAA)

The assessment is based on input from representatives of the three DoD organizations listed here.

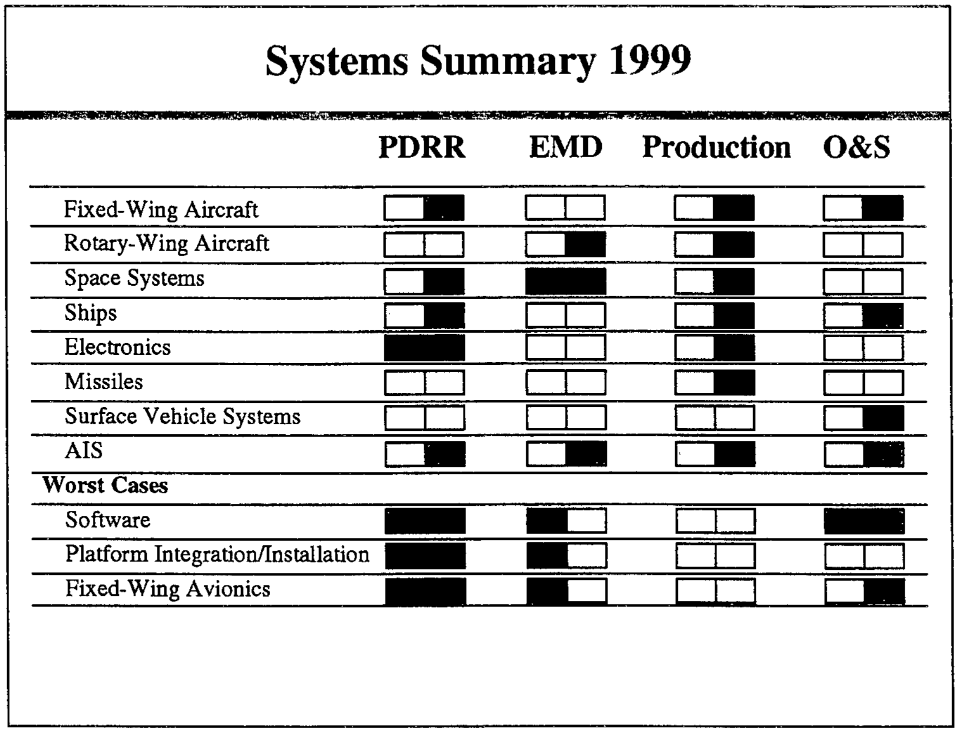
AIS Studies

- "Open" Estimating Tool for Software Intensive Programs with COTS Hardware and Software (ESC/Tecolote)
- AIS Software Development and Maintenance Database (NCCA/TASC)

This slide lists two recently completed and ongoing AIS studies. The sponsoring and performing organizations are shown in parentheses (sponsor/performer). It remains to be seen whether the results of these studies will translate into improved cost-estimating capability.

X. SUMMARY/OSD PERSPECTIVE

Vance Gordon, OSD Cost Analysis Improvement Group



This slide summarizes my colleagues' presentations. As Steve Balut predicted, the uncertainty of our estimates is greatest at Milestone (MS) I and II, and decreases as we approach production. This is not new news, but it is a more systematic view than we have previously been able to present.

It is, moreover, important to bear in mind that this picture captures our uncertainty at each milestone. If a similar chart were prepared for our uncertainty *at MS I* of the costs of each phase, it would be far more red than this one. It would be a little better at MS II, where we generally have some data from PDRR to buttress our models, than at MS I, but it would still present a daunting picture.

The problems that should receive the highest level of research attention are those that combine uncertainty with immediacy, that is, estimating functions where our tools are weak and demand is projected to be high. The following slides outline projected demand over the next few years for each of the systems shown here.

Upcoming Reviews—Fixed-Wing Aircraft

- 1999

F-22	LRIP

- 2000

JPATS	MS III
F/A-18E/F	MS III
E/2C Repro.	MS III
V-22	MS III

- 2001

B-1B CMUP	MS III
JSF	MS II

- 2003

F-22	MS III

- 2005

JSF	MS III

During the next 5 years, fixed-wing aircraft will present serious challenges to our estimating capabilities and impose the most costly acquisition decisions on the Department's acquisition executives. If we accept the view that research produces improved capabilities no sooner than 1 to 2 years after its inception, our attention is drawn forcibly to 2001, the JSF Milestone II decision and the need to improve our capabilities to estimate the costs of fixed-wing avionics and software.

Upcoming Reviews—Rotary-Wing Aircraft

• 2000		• 2004	
SH-60R	LRIP	Comanche	LRIP
• 2001		• 2006	
Comanche	MS II	Comanche	MS III
H-1 Upgrade	LRIP		
• 2002			
SH-60R	MS III		

The Comanche Milestone II review poses the same challenges on about the same schedule as the JSF Milestone II. Estimation of platform integration, software, and avionics are the critical areas here as well.

Upcoming Reviews—Space Systems

- 1999

NESP	LRIP
Patriot PAC-3	LRIP
MM III GRP	MS III
MM III PRP	LRIP
NMD	PR

- 2000

GBS	MS III
SBIRS	MS II

- 2001

NPOESS	MS II

- 2003

SBIRS	MS III

The green/yellow assessments for space in the summary slide probably underestimate the challenges of estimation for the programs shown here. The recent vicissitudes of the SBIRS program and the complexity of NMD software emphasize the need for research that will illuminate the complexity of these systems.

While the critical reviews are scheduled too soon to expect results from research projects not yet begun, any program stretches would permit the development of refined tools for our analyses. It is an unhappy prospect, but it seems possible that such stretches will occur. Again, the critical areas are integration and software.

Upcoming Reviews—Ships

- 1999
  - Strategic Sealift — MS III
- 2002
  - SSN-774 — PR
- 2003
  - DD-21 — MS II
- 2007
  - LPD-17 — MS III
  - SSN-774 — MS III
- 2011
  - DD-21 — MS III

The summary slide suggests that our tools for estimating the costs of ships are relatively sharp, compared to those for other systems, at every phase of development. The DD-21 review in 2002 will present the first critical decision, which might be affected by research begun now. Again, software and integration costs will loom large in the analysis.

Upcoming Reviews—Missiles

- 1999

THAAD	MS II
MM III GRP	MS III
MM III PRP	LRIP
NMD	PR
MLRS Upgrade	MS III

- 2000

AIM-9X	LRIP
Patriot PAC-3	MS III
JASSM	LRIP
Navy Area TBMD	PR
MM III PRP	MS III
NMD	PR

- 2001

Tactical Tomahawk	MS III

- 2002

JASSM	MS III
AIM-9X	MS III

- 2003

Navy Area TBMD	MS III

- 2004

THAAD	LRIP

- 2007

THAAD	MS III

The redundancy between this slide and the slide summarizing upcoming space reviews results from the complexity of missile defense systems. The cross-cutting theme remains the uncertainty of our software and integration estimates.

Upcoming Reviews—Surface Vehicles

- 1999
  - HMMLTV — MS I
  - Bradley Upgrade — MS III
- 2000
  - Crusader — MS II
- 2001
  - AAAV — LRIP
- 2003
  - Crusader — LRIP
- 2005
  - AAAV — MS III
  - Crusader — MS III

This area is dominated by two programs, Crusader and AAAV. The concerns they raise center on their high complexity relative to earlier generations of surface systems and, thus, on their integration and software costs.

Pre-MDAP Programs

- Fixed-Wing Aircraft
  - C-130 AMP
  - Tactical UAV
  - HAEUAV
  - AEW
- Rotary-Wing Aircraft: None
- Missiles: None
- Space
  - Advanced Early Warning
- Surface Vehicles
  - FCS (M-1 follow-on)
  - FIV (Bradley follow-on)
  - FSCS
- Ships
  - ADC(X)
  - CV(X)

These are some of the programs we can expect to deal with in the years that follow completion of the current Major Defense Acquisition Programs (MDAPs). There will surely be others. We cannot say precisely what research will be needed to prepare our estimates, but it is clear that much more of the same will be needed. A better understanding of software and integration costs will remain the order of the day.

XI. CLOSING

Stephen J. Balut, Institute for Defense Analyses

What's Next

- Document this assessment
- Update cost research road map
- Review ongoing cost research and catalog projects
- Prepare FY 1999 cost research program
  - Decentralized
  - Informed

Now, I want to let you know what comes next for cost research in the DoD, and where you can get more information about cost research.

Our panel will document the assessment you've just seen and place it on the Internet. Documentation will include the slides you'll see here along with backup materials used to develop the scores.

Over the next few months we will be updating the DoD Cost Research Plan in light of what you've seen here today. The updated plan is intended to guide subsequent research investments to areas of greatest need.

Next, we will review ongoing research activities at the IDA/CAIG Cost Research Symposium to be held in May. A draft catalog of projects in progress or planned will be given to participants at that time. This catalog will be finalized in August and placed on the World Wide Web.

Then we get to the real purpose of this cycle of annual planning. During the summer, sponsors will select topics for study during FY 2000. They will make these selections in a decentralized way, but their decisions will be informed by the assessments at DoDCAS, the updated road map, and knowledge of the current status of ongoing cost research as contained in the Cost Research Symposium catalog.

Cost Research Information

- Research results
  - DTIC
  - WWW.ASAFM.ARMY.MIL/CEAC#
  - WWW.NCCA.NAVY.MIL
  - WWW.AFCAA.AF.MIL
  - WWW.RA.PAE.OSD.MIL/ADODCAS
- Ongoing research
  - IDA catalog on Web
  - Cost research database under development
- Documentation of this assessment will be distributed and put on Web
- Update to 6-year cost research road map will be distributed and put on Web

This slide shows where you can go to get more information on cost research. Many completed studies are sent to the Defense Technical Information Center (DTIC). Studies that are not sent to DTIC are sometimes made available by the sponsoring office directly. In some cases, results are placed on Web sites. This slide lists some of those sites.

The only place to get a broad view of ongoing research is in the catalog produced in conjunction with the Cost Research Symposium. The catalog is placed on the Web. For example, the 1998 catalog is now on the OSD ADODCAS site as a Portable Data Format (PDF) file readable with Adobe Acrobat Reader.

Also, the CAIG is developing a cost research database and will make it available to users when completed.

Documentation of the assessments you'll hear today will be placed on the ADODCAS Web site. The update to the DoD 6-Year Cost Research Plan will be put on the same site.

ABBREVIATIONS

AAAV	Advanced Amphibious Assault Vehicle
AACEI	ASSET/ACEIT Interface
ABL	Airborne Laser
ACDB	Aircraft Cost Data Base
ACEIT	Automated Cost Estimating Integrated Tools
ADC(X)	Auxiliary Dry Cargo Ship
ADoDCAS	Annual DoD Cost Analysis Symposium
AEW	Airborne Early Warning
AF	Air Force
AFCAA	Air Force Cost Analysis Agency
AFMC	Air Force Material Command
AFTOC	Air Force Total Ownership Cost
AIS	automated information system
AMCOM	Aircraft and Missile Command
AMP	Aircraft Modernization Program
AMRAAM	Advanced Medium-Range Air-to-Air Missile
APAM	Antipersonnel/Antimaterial
APN	Aircraft Procurement, Navy
ASC	Aeronautical Systems Center
ASSET	Advanced Surface Ship Evaluation Tool
ATACMS	Army Tactical Missile System
ATIRCM	Advanced Threat Infrared Countermeasures
AWACS	Airborne Warning and Control System
BAT	Brilliant Anti-Tank
BIT	built-in test
BITE	built-in test equipment
BMDO	Ballistic Missile Defense Organization
C^3	Command, Control, and Communications
CAIG	Cost Analysis Improvement Group
CAIV	Cost As an Independent Variable
CARD	Cost Analysis Requirements Description
CCDR	Contractor Cost Data Reporting

CEC	Cooperative Engagement Capability
CECOM	Army Communications and Electronics Command
CER	cost-estimating relationship
CMUP	Conventional Mission Upgrade Program
CMWS	Common Missile Warning System
COMP UP	Computer Upgrade
COTS	commercial off-the-shelf
CPR	Cost Performance Report
CR	cost research
CRS	Cost Research Symposium
CV(X)	Carrier
D&V	Demonstration and Validation
DAB	Defense Acquisition Board
DMSP	Defense Meteorological Satellite Program
DoD	Department of Defense
DoDCAS	DoD Cost Analysis Symposium
DSCS	Defense Satellite Communications Systems
DSUP	Defense System Upgrade Program
DTIC	Defense Technical Information Center
EELV	Evolved Expendable Launch Vehicle
EHF	Extremely High Frequency
EMD	Engineering and Manufacturing Development
ESC/FMC	Air Force Electronics Systems Center
EVM	Earned Value Management
FCS	Future Combat System
FIV	Future Infantry Vehicle
FMTV	Family of Medium Tactical Vehicles
FSCS	Future Scout and cavalry System
FYDP	Future Years Defense Plan
GBS	Global Broadcast Service
GPS	Global Positioning System
GRP	Guidance Replacement Program

HAEUAV	High-Altitude Endurance Unmanned Airborne Vehicle
HM&E	hull, mechanical and electrical
HMMLTV	High Mobility Multipurpose Light Vehicle
IA&T	Integration, Assembly and Test
IDA	Institute for Defense Analyses
IPT	Integrated Product Team
IT	Information Technology
JASSM	Joint Air-to-Surface Standoff Missile
JDAM	Joint Direct Attack Munition
JPATS	Joint Primary Aircraft Trainer System
JSF	Joint Strike Fighter
JSOW	Joint Standoff Weapon
JSTARS	Joint Surveillance Target Attack Radar System
LCC	life-cycle cost
LMI	Logistics Management Institute
LRIP	Low-Rate Initial Production
MACDAR	Military Aircraft Data and Retrieval System
MCR	Management Consulting and Research, Incorporated
MDAP	Major Defense Acquisition Program
MILSTAR	Military Strategic, Tactical and Relay
MIS	Management Information System
MLRS	Multiple-Launch Rocket System
MM	Minuteman
MOD	Ministry of Defence
MS	Milestone
MTBF	mean time between failures
NAVAIR	Naval Air Systems Command
NAVSEA	Naval Sea Systems Command
NAVSTAR	Navigational, Strategic, Tactical and Relay
NCCA	Naval Center for Cost Analysis
NESP	Navy Extremely High Frequency SATCOM
NMD	National Missile Defense

NPOESS	National Polar-Orbiting Operational Environmental Satellite System
NSWC	Naval Surface Warfare Center
NSWCCD	Naval Surface Warfare Center Carderock Division
O&M	Operations and Maintenance
O&S	Operations and Support
ONR	Office of Naval Research
OPN	Other Procurement, Navy
OSCAM	Operating and Support Cost Analysis Model
OSD	Office of the Secretary of Defense
OSMIS	Operating and Support Management Information System
P&A	pay and allowances
PA&E	Program Analysis and Evaluation
PAAM	Performance Assessment Analysis Model
PARM	Participating Manager
PCS	Permanent Change of Station
PDF	Portable Data Format
PDRR	Program Definition and Risk Reduction
PM	Program Manager
PODAC	Product-Oriented Design and Construction
PR	Production
PRP	Propulsion Replacement Program
RDT&E	Research, Development, Test and Evaluation
RSIP	Radar System Improvement Program
SAF	Secretary of the Air Force
SAIC	Science Applications International Corporation
SAR	Selected Acquisition Report
SBIRS	Space-Based Infrared Systems
SCN	Ship Construction, Navy
SE/PM	Systems Engineering/Project Management
SHAPM	Ship Acquisition Program Manager
SMC	Space and Missile Systems Center
SMDC	Strategic Missile Defense Command

SSDC	Space and Strategic Defense Command
TASC	The Analytical Science Corporation
TBMD	Theater Ballistic Missile Defense
THAAD	Theater High-Altitude Air Defense
UAV	Unmanned Airborne Vehicle
USACEAC	U.S. Army Cost and Economic Analysis Center
USATACOM	U.S. Tank-Automotive and Armaments Command
USCM	Unmanned Space Vehicle Cost Model
USMC	U.S. Marine Corps
VAMOSC	Visibility and Management of Operation and Support Cost
WBS	work breakdown structure

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13. ABSTRACT *(Maximum 200 words)*

Suppose you are the cost analyst responsible for estimating the cost of a weapon system in preparation for a major milestone review (e.g., Milestone II, Engineering and Manufacturing Development). Do you have the data, methods (e.g., cost-estimating relationships), and tools (e.g., automated models) you need? Representatives from each of the Military Departments answered these questions for all major commodity types at the Annual DoD Cost Analysis Symposium held on February 3–5, 1999. The Air Force representative addressed space systems and fixed-wing aircraft; the Navy representative discussed ships, electronics, and automated information systems; and the Army representative addressed missiles, rotary-wing aircraft, and surface vehicle systems. A representative from the OSD Cost Analysis Improvement Group (CAIG) summarized the findings and added the OSD perspective. He also provided highlights of the upcoming Defense Acqusition Board schedule where these estimates will be needed. The findings of this panel will be used to revise the DoD Six-Year Cost Research Plan that will guide future investments in DoD cost research.

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